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# THE CLAYS OF NORTH DAKOTA.

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## INTRODUCTION AND GENERAL GEOLOGY.

North Dakota is essentially a flat prairie state. Extending westward thirty to forty miles from the Red river, which forms its eastern boundary, is a smooth plain, once the bottom of the glacial lake Agassiz. This has an elevation from 800 to 1,000 feet above sea level at the river, and rises gently to the west. In its northern part the plain is bounded on the west by a sharp escarpment, 500 or 600 feet high, known as the Pembina Mountains. Generally, however, the border is marked plainly, though less sharply, by gravel ridges or old beaches, a few feet in height. West of this plain is a region, 1,200 to 1,600 feet above the sea, in which wide stretches of flat prairie are interspersed with low moraines. The outmost moraine is the limit of the Wisconsin drift, and extends in a broad belt across the state, roughly parallel to the Missouri river and a few miles east of it. Its elevation ranges from 1,800 to 2,700 feet above sea level. Beyond the moraine, and in the southern part of the state west of the Missouri, is a rolling prairie incised by a rather mature river system. The topography is such as is developed in flat-lying, unconsolidated strata in a semi-arid climate, in which the rains are torrential. Along the rivers are bad-lands or "breaks," sometimes a few miles in width. The divides are broad rolling prairies, with here and there conspicuous buttes saved from erosion by cap-

pings of firm rock, which rise a few hundred feet above the general level, or to heights of 3,000 feet or more above sea level.

The geology of the state is even more simple than the topography. The oldest rocks which outcrop are of upper Cretaceous age. Under the three hundred feet of lake deposits and drift in the Red river valley, lie the older Paleozoic and crystalline rocks, but these play no part in the present configuration of the state. All the surface rocks are soft and are but little changed from the condition in which they were laid down. All of the sediments with one exception, a slight anticline which occurs in the southwestern part of the state, are practically horizontal, although of course continental uplift and depression have changed their original elevations.

Underlying the east central part of the state and for the greater part covered by glacial drift are the upper Cretaceous deposits. The Dakota sandstone does not outcrop, but is an important water horizon in this section. The Benton is exposed in the deep cuts of the rivers in the Pembina Mountains, and Upham[1] reports it also in the southern part of the state, in the valley of the Sheyenne. The Benton consists of a rather unconsolidated clay shale. The Niobrara, which conformably overlies the Benton, also outcrops in the Pembina Mountains and in the Sheyenne valley. The Niobrara is calcareous, and the sediments range from a calcareous clay shale to a cement marl, and even to an impure chalk. The Pierre, although covered by glacial drift, directly underlies the greater part of this east central belt. It is also an unindurated clay shale. The Fox Hills sandstone is not important in North Dakota, although it probably outcrops in the southern part of the state near the Missouri river and underlies the greater part of the western portion, where it is covered by the Laramie sands and clays.

The Laramie occupies the entire western half of the state, although part of it is overlain by drift, and in some places by Tertiary sediments. It is well exposed by the Missouri and its

[1] The glacial Lake Agassiz. U. S. Geological Survey, Monograph XXV., 1895.

numerous tributaries and also in the buttes. It consists principally of unconsolidated sands and clays. Locally the clays are somewhat hardened and the sands consolidated. Associated with these sediments are beds of lignite, thin seams of iron ore, and gypsum-bearing clay beds.

Overlying this formation is one which consists almost entirely of clay. Some of these clays are very high grade, and they are remarkably uniform over an area of some 4,000 square miles, with its center at Dickinson. This formation is in turn overlain by a thick deposit of sand, which in places is consolidated and forms the capping rock of the high buttes. At the base of this upper formation the writer found the skull of a mammal, which has been identified as an Oligocene ruminant, *Eporeodon major*. This has led him to place these overlying clays and sands, which represent an entire change of conditions from those existing during the coal period, in the Tertiary, although they have hitherto been classed as Laramie.

Along the western border of the state, west of the area in which the clays occur, the coal measures extend up into the same horizon as that in which the high grade clays are found. In this state there seems to be no lithological break between the two coal horizons, but in Montana Doctor Leonard, who for two seasons has been working in that region, informs me that the change is fairly well marked, and he places the upper coal beds in the Fort Union. It is of course impossible, except on paleontological evidence which as yet is very insufficient, to definitely assign the beds to their proper chronological divisions. However in the region with which this article deals, the area of high grade clays, the lithological difference is most marked. In this area the lowest outcropping formation is the "coal measures" and it is placed in the Laramie, although the upper part may be Fort Union. The overlying formations are considered Tertiary.

The Pleistocene deposits have already been touched upon, and as their clays do not present any unusual or especially valuable features, they need not be further considered.

CLAYS OF THE BENTON, NIOBRARA AND PIERRE.

The clays of the Benton, Niobrara and Pierre formations extend across the east central part of the state in a broad belt, a hundred miles or more in width. The Benton is the lowest of the North Dakota Cretaceous and is the oldest sedimentary formation exposed in the state. In the Pembina Mountains it attains its best development. It consists of about 150 feet of dark fissile clay shales, the dark color being due to carbonaceous matter. The beds retain their original position and the clay has been but little hardened. It is soft, and easily mined and prepared. Near the base some of the carbonaceous matter has been decomposed, and the shales have a strong odor of petroleum. Small ferruginous concretions are abundant. They are pyritic and seem to have been formed by the reduction of the sulphate by carbonaceous material. Some of the sulphate, which occurs in thin seams of gypsum, has been reduced to native sulphur, which is seen in yellow streaks and patches on the weathered clay.

The shale becomes quite plastic on being ground or when weathered, but is sticky when wet. It burns red, and becomes hard at low temperatures. There is a considerable difference between the temperatures of incipient fusion and viscosity, so that the clay can be vitrified safely. The fusibility is low, due principally to the large amounts of iron, lime, and magnesia. The amount of lime increases greatly near the top and also the sulphur, due of course to the presence of more and more gypsum.

This large amount of gypsum near the top, which is accompanied by a decrease in iron and alumina, makes the clay much less desirable and even practically worthless. Unless very great care is taken in burning, this clay fuses incipiently at low temperatures before all the sulphur is driven off, and as vitrification is approached the sulphur dioxide which is formed is imprisoned and bloats the clay, making the product valueless. The clay near the base, however, is suitable for bricks, hollow ware and tile.

The Niobrara, which overlies the Benton, is not sharply differentiated from it. The two grade into each other, the most notable difference being the increase in calcium carbonate upwards. The calcium carbonate in the Niobrara ranges from twenty to seventy-five per cent., which of course renders the material useless as a clay. Certain beds, however, near the top are valuable for the manufacture of cement.

The main part of the strata classified as Niobrara, locally known as "cement rock," is a rather hard, massive, calcareous shale or marl. It is olive green to drab in color, and is spotted with white specks of calcite. The total thickness is about 125 feet.

The Pierre conformably overlies the Niobrara and forms the uppermost horizon of the Cretaceous shales. It is exposed wherever the rivers have cut through the drift, and it is thus available at many places. It is quite uniform throughout its entire extent. The shales are dark gray or black, are very fissile, and weather into thin flakes. Small iron concretions are abundant. The shales, except near the base, are for the most part low in lime.

The base of the Pierre or the top of the Niobrara is marked by a peculiar horizon of banded black and white and red shale which is very characteristic and remarkably persistent, being essentially the same in the Pembina Mountain region and at Valley City, localities separated by some 150 miles. It is from four to six feet thick. The individual red and white bands are thin, not more than an inch or two wide. The red bands are mostly iron oxide, while the white bands are a soft, cheesy silica. They also contain gypsum, and other sulphates and soluble salts. The black bands are carbonaceous clay.

The Pierre reaches its maximum thickness of over three hundred feet in the Pembina Mountains. The lower part is a black, highly carbonaceous shale, which weathers into small thin scales. It is readily prepared and develops good plasticity, but the wet clay is very sticky. The air and fire shrinkages are high. The clay burns red and has a considerable range of temperature

between the points of incipient fusion and viscosity. Trouble in burning is caused by the large amount of gypsum and pyrite and by sulphur derived from the gypsum. At the very base of the deposit the checking on burning is so excessive that the clay is of no value. About 200 feet from the bottom the shales are more massive and compact. The clay is fine grained and has a very good plasticity. It is lighter colored and much more free from impurities, carbonaceous matter, gypsum, and pyrite. It burns red, the temperatures of incipient fusion and viscosity are widely separated, and the clay is of a semi-refractory nature. This clay is of good quality for earthenware and the cheaper grades of stoneware.

All of the above clays are of marine origin, but the next formation of importance, the Laramie, was deposited in fresh or brackish water. None of the clays just described are of high grade; their fusibility is low, they burn red, and although they are plastic the majority of them are sticky. This stickiness seems to be related to the amount and kind of carbonaceous material present. They are very uniform over wide areas, and were probably deposited in an open sea. Quiet water existed in the middle of the period during which the upper Benton and Niobrara were deposited. The origin of the peculiar deposit of black and white banded shale, which marks the boundary between the Niobrara and Pierre, is obscure. Possibly gypsum was thrown down from sea water along with the carbonaceous clays, due to a shoaling of the water and subsequent evaporation. This gypsum may have been converted to sulphuric acid, which, reacting on the black clay, dissolved the clay substance and left the silica behind in the soft, impalpable state in which it is found. This was followed by a more settled period of muddy water, during which the Pierre shales were accumulated. Conditions were not favorable at any stage during these upper Cretaceous periods for the formation of high grade clays, since rapid deposition and chemical precipitation caused many impurities to be mixed and deposited with the transported clays.

LARAMIE AND TERTIARY CLAYS.

The three divisions of the Laramie formation have already been referred to. At the bottom is a great series of sands, lignite, and impure clays. Above these are beds, not more than a hundred and fifty feet in total thickness, in which occur the high grade, light burning, more refractory clays. No lignite of any importance exists with these beds. On top there is a layer of sand, some three or four hundred feet thick, part of which is cemented into a firm calcareous sandstone. For reasons already given the coal measures are best placed in the Laramie and the overlying formations in the Tertiary.

The coal measures extend over the entire area and outcrop wherever erosion has progressed far enough. The lowest elevation of the Laramie at its eastern boundary is from 1,500 to 1,600 feet above sea level, and in a well at Medora, twenty-five miles from the Montana line, it has been found about 1,350 feet above sea level. As the coal beds are horizontal, it would seem that the sediments were laid down in a basin which covered the western half of the state and extended into Montana and South Dakota. The highest elevation which the coal measures attain, where they are overlain by the white clays, is about 2,450 feet above the sea. In the extreme western part of the state, workable coal seams are found at least at an elevation of 2,800 feet above sea level. In eastern Montana, however, the coal measures continue up into the known Tertiary (Fort Union) beds without any decided break, so that it is possible that the high coal seams along the western boundary of North Dakota are Fort Union.

The beds are essentially horizontal. The most striking feature of the Laramie is the rapid alternation of sediments. At Medora there are at least seventeen lignite seams between the river level and the top of Sentinel Butte, a distance of about 860 feet.[1] This feature is also very well shown by one of the typical sections along the Missouri river.[2]

[1] Dr. A. G. Leonard, N. Dak. Geol. Survey, Vol. III., p. 168.

[2] *Ibid.*, p. 158. Dr. F. A. Wilder also gives a section in this journal, I., 675 (1906).

SECTION AT THE BIG BEND OF THE MISSOURI RIVER TWO MILES NORTHWEST OF COAL HARBOR.

| | Feet. | Inches. |
|---|---|---|
| 38. Drift | 30 | |
| 37. Clay shale, chocolate brown below, gray above | 5 | |
| 36. Lignite seam | 3 | 6 |
| 35. Clay shale | 1 | 6 |
| 34. Fine, argillaceous sand | 8 | |
| 33. Gray, laminated clay shale | 5 | |
| 32. Lignite seam | | 3–5 |
| 31. Gray clay shale | 5 | |
| 30. Sandy, gray clay stained yellow in spots by iron oxide | 6 | |
| 29. Brown clay shale with thin lignitic partings | | 6–10 |
| 28. Light gray clay, growing sandy above | 5 | |
| 27. Gray, sandy clay with ferruginous nodules and yellow, limonitic bands | 20 | |
| 26. Clay shale, gray and yellow in alternating layers, with thin, yellow, limonitic bands | 4 | |
| 25. Brown and black, brittle, coaly shale | 1 | |
| 24. Brown clay shale | 1 | |
| 23. Lignite seam | | 6–8 |
| 22. Brown, clay shale with plant remains | | 10 |
| 21. Lignite seam | | 2–3 |
| 20. Clay | | 2 |
| 19. Fine, argillaceous sand | 3 | |
| 18. Gray clay shale | 1 | |
| 17. Thin lignite seam | | ½ |
| 16. Gray and yellow clay shale in alternating layers | 4 | 6 |
| 15. Clay shale, chocolate brown | 4 | |
| 14. Lignite seam | | 10 |
| 13. Clay shale, gray, weathers into thin flakes | 1 | 6 |
| 12. Gray and yellow, sandy clay with ferruginous nodules | 10 | |
| 11. Lignite seam with some coaly shale | | 8 |
| 10. Gray clay shale | 4 | |
| 9. Lignite seam and brown carbonaceous clay | | 2 |
| 8. Gray, sandy clay, stained yellow in spots by iron oxide. Contains very many sandy ferruginous nodules, distributed mostly in bands. Also contains large sandstone concretions and lenses | 31 | |
| 7. Gray and yellow argillaceous sand | 4 | |
| 6. Gray clay, with no sand, and containing nodules of iron oxide | 1 | |
| 5. Lignite seam | 3 | |
| 4. Gray clay shale | 1 | |
| 3. Lignite seam, entire thickness not exposed, but at least | 4 | |
| 2. Sandy clay shale | 10 | |
| 1. Unexposed to river | 15 | |

NORTH-

Inches.

6
6

3–5

6–10

6–8
10
2–3
2

½
6

10
6

8

2

Although not shown in the above section, beds of clay containing much gypsum are very common. The limonite bands and ferruginous concretions in unconsolidated sands are also very characteristic.

As would be expected from the shifting character of the sediments, the individual beds are of very slight lateral extent. Many of them are traceable only for a mile or less, and even the thickest beds thin out in a few miles. The largest coal seam yet reported in the state, at Russell's ranch on Sand creek, is thirty-four feet thick, but in five miles it dwindles to six feet, and two miles further on disappears. This thinning out is true in a greater degree of the smaller seams of coal and of the clay and sand deposits as well. The beds have therefore the shape of elongated overlapping lenses, separated here and there by more persistent beds of sand.

The clays usually directly overlie lignite, but clay beds are also interstratified with sand, and sand may rest upon lignite. They are very impure, and contain, besides sand, much carbonaceous, ferruginous, and calcareous material. The colors are dark bluish gray or olive.

Their physical properties vary widely. The plasticity is generally good, but some of the sandy clays are only moderately plastic. The shrinkage, both air and fire, is high, so that many of the clays check badly on drying and burning. They usually burn to a red shade, although those high in lime burn to a buff or orange color. They are all of low fusibility, the most refractory sample tested becoming viscous at 2,450 degrees Fahrenheit. The majority of them have a considerable range between incipient fusion and viscosity, but the sandy, and highly calcareous ones have but a range of about one hundred degrees. They can be burned dense, but the large fire shrinkage usually causes them to crack badly.

The Laramie clays are therefore not of great economic importance. The greater part of them are sandy and are useless. Those which are plastic enough to be used, generally have a high air shrinkage, and even in the manufacture of common brick trouble is experienced from checking. Some of them,

however, can be used by the stiff-mud process for the manufacture of brick and common red earthenware. It is doubtful if any of the clays can be vitrified without injury. All commercial experiments in making vitrified wares from these clays have been failures or only partially successful.

Overlying the coal measures and extending as far west as the divide of the Little Missouri river is a series of clay beds, some of which are of a very high grade. They have a thickness of from 50 to 150 feet, and occur at elevations between 2,450 and 2,600 feet above sea level. Consequently they are found only in the buttes and divides. The area underlain by the high grade clays is approximately fifty miles east and west, by ninety miles north and south. Its eastern limit, which is roughly a meridian through the town of Hebron, is determined by the degradation of the land below the 2,450-foot contour by the streams emptying into the Missouri. To the north also the clays have been eroded away and to the south they change in character, becoming calcareous and of low grade.

Over the clays, and extending from 300 to 400 feet above them, is a great thickness of sand which has been locally cemented by calcareous or ferruginous material into a soft sandstone. This sandstone forms the protecting cap of all the high buttes, saving them from erosion. This formation reaches its maximum development, of about 400 feet, in the Kildeer Mountains, two high buttes forty miles north of Dickinson, which attain an elevation of over 3,000 feet above the sea. A great deal of the sand is soft and unconsolidated and is only protected from very rapid erosion by the overlying layers of firm sandstone. No clays are found within this formation.

The high-grade clays lie on both sides of the Northern Pacific railroad. The general elevation of the country being lower to the south, the clays are therefore more abundant north of the track. They are best developed along the railroad and a few miles to the north, in the neighborhood of Dickinson, Gladstone, and Hebron. Here are 10 to 20 feet of very pure, plastic clays overlying from 30 to 50 feet of white, sandy, fire clays.

The clays of this horizon, especially the white, sandy ones,

are, considering the large area over which they were deposited, remarkably uniform. They vary a good deal in their physical properties, but are much alike in composition. Except in the southwestern part of the area, they are generally low in lime and other fluxing constituents, but are high in silica. They are refractory, and usually burn white, gray, or buff. They are compact, massive, structureless clays, at times laminated but rarely shaly and vary in texture from extremely fine-grained varieties to sandy ones with but little clay substance. They are soft and easily prepared. The great majority of the clays show good plasticity, even the sandy ones being fairly plastic. The air shrinkage is low, averaging about five per cent., and the clays dry without cracking. Although the clays are generally refractory, it is doubtful if any are fire clays of the best sort, on account of the large amount of silica which acts as a flux at high temperatures. The white, sandy clays are the most refractory and many of them are unaffected at 3,000 degrees Fahrenheit. Most of the plastic clays fuse at temperatures below this, but they are remarkable for the wide range between the points of incipient fusion and viscosity. A selected sample from a deposit north of the track between Gladstone and Dickinson showed a difference of 900 degrees. Many of the others have a range of from 600 to 800 degrees. The fire-shrinkage is fairly high in the very fine grained clays, but even these do not check or warp when burned. Most of the clays, as already stated, burn to light colors, some, however, which are high in iron give mottled buff and dark brown products.

The character and properties of these clays may be more fully understood by an examination of a typical deposit in more detail. The following section is exposed a mile southwest of the town of Dickinson:

| Section of Clay-deposit near Dickinson. | Feet. |
|---|---|
| 5. Hardened sandy clay | 1½ |
| 4. White, fine grained, rather sandy clay | 10 |
| 3. Light gray or blue, fine grained clay | 2 |
| 2. Grayish blue, fine grained, carbonaceous clay, ferruginous near the base | 5 |
| 1. White, sandy clay | 8 |
| Yellow ferruginous sand | 30 |
| Sand, impure clays, and lignite. | |

The analyses of these clays is shown in the following table:

CHEMICAL ANALYSIS OF NORTH DAKOTA CLAYS.

| | I | II. | III[1]. | IV[1]. |
|---|---|---|---|---|
| Silica ($SiO_2$) | 73.20 | 66.55 | 64.84 | 72.66 |
| Alumina ($Al_2O_3$) | 18.56 | 23.22 | 24.31 | 17.33 |
| Ferric Oxide ($Fe_2O_3$) | 0.50 | 1.16 | 1.60 | 1.05 |
| Lime (CaO) | 0.29 | 0.29 | 0.11 | 0.13 |
| Magnesia (MgO) | 0.52 | 0.61 | 0.24 | |
| Potash ($K_2O$) | 0.36 | ..... | trace | 0.36 |
| Soda ($Na_2O$) | 0.38 | ..... | 0.32 | 0.38 |
| Loss on Ignition | 5.93 | 7.09 | 8.58 | 9.35 |

Their physical tests are shown in detail in the table below:

TABLE SHOWING PHYSICAL PROPERTIES OF NORTH DAKOTA CLAYS.

| | I. | II. | III. | IV. |
|---|---|---|---|---|
| Water required | 22.6 % | 24.9 % | 25.2 % | 25.9 % |
| Plasticity | moderate | very good | very good | very good |
| Air-shrinkage | 2.0 % | 4.6 % | 4.7 % | 4.4 % |
| Tensile strength | 90 lbs. | 187 lbs. | 138 lbs. | 94 lbs. |
| Cone 05, 1922° F. | | | | |
| Fire-shrinkage | —0.3 % | 1.0 % | 1.0 % | 0.8 % |
| Color | pink white | light pink | light pink | pink white |
| Cone 1, 2102° F. | | | | |
| Fire-shrinkage | 0.9 % | 5.4 % | 6.0 % | 4.7 % |
| Color | cream white | light buff | light buff | light buff |
| Cone 5, 2246° F. | | | | |
| Fire-shrinkage | 2.0 % | 7.2 % | 6.6 % | 6.7 % |
| Color | white | light gray | gray white | light buff |
| Absorption | 14.1 % | 4.7 % | 2.4 % | 5.1 % |
| Cone 10, 2426° F. | | | | |
| Fire-shrinkage | 2.5 % | 7.7 % | 9.0 % | 6.0 % |
| Color | white | gray white | white | light gray |
| Absorption | 13.1 % | 3.0 % | 0.5 % | 2.1 % |
| Incipient fusion | unaffected | 2318° F. | 2174° F. | 2318° F. |
| Vitrification | at cone 25. | 2570° F. | 2498° F. | 2714° F. |
| Viscosity | | 2858° F. | 2966° F. | 3000°+F. |

The very best clays, those of the above character, occur within a few miles of the railroad. North of the track for forty miles they are very abundant, but as a rule they are neither so thick nor so pure as near the line, being generally higher in iron, although otherwise they are of the same high character.

The highest grade clays have been manufactured into stoneware and pottery, and even into the best grades of china. There is also much variety, so that many different products could be manufactured, as has been shown not only in the laboratory, but

[1] E. J. Babcock, N. Dak. Geol Survey, Vol. I., p. 55.

also in eastern factories. At present their full value is far from being realized, pressed and fire brick only being made from them. Their future economic value, however, will undoubtedly be great.

### GENESIS OF THE LARAMIE AND CRETACEOUS CLAYS.

This marked difference between the clays of the coal measures and those above them gives added support to the distinction between the two groups of formations already made in the section on the general geology of the region. There must have been a decided change in the conditions existing during the time in which the two series of beds were deposited. The skull of the *Eporeodon major,* which was found near the base of the overlying sand beds, in the Chalk Buttes near Sand Creek, shows that the upper formation is Oligocene in age, and substantiates the conclusion that the clay horizon is Tertiary, probably Eocene.

The most striking feature that has been pointed out in the Laramie formation is the rapid change in the character of the sediments in both vertical and lateral directions. This indicates a very unstable condition during the period of their deposition. Such a condition would be expected during the Laramie, a well-recognized transition period. The difference between these coal measures and those of the Carboniferous is important. In the Carboniferous period the beds are thicker and, although alternating rapidly, they are much more persistent. Shale (indurated clay) is much more commonly in immediate association with the coal in the Carboniferous deposits than in the Laramie. While all the under clays of the Carboniferous are not by any means fire clays, many of them are and they are generally much purer than the Laramie coal clays. Sand is more abundant, and in closer association with the coal in the Laramie than in the Carboniferous. No limestone or marl is found in the North Dakota coal measures, although all of the sediments are notably calcareous. Silicified wood occurs sometimes in great abundance.

Possibly the best explanation, and the one most widely accepted, is that the Carboniferous coals were formed on coastal

plain areas, such as exist to-day in southern Florida. The character of the North Dakota coal measures would indicate, however, a more rapid accumulation, and more rapidly changing conditions. The supposed marshes in which the carbonaceous matter gathered were more transient, and less extensive. Impure clays were deposited, and much sand. The association of the coal with the clays seems to have had no effect on the properties of the clay other than to make them carbonaceous. The generally accepted view, supported by C. A. White[1] in his correlation paper on the Cretaceous, is that the Laramie sediments were deposited in large bodies of fresh and brackish water. The conditions were very unstable because of the epirogenic movements which were then affecting the Rocky mountain region. From the examination of the Laramie as it exists in North Dakota, I conclude that the sediments were deposited in transient fresh-water lakes, alternating with marsh and land conditions, during which forests flourished and carbonaceous matter accumulated. Rapid erosion, associated with slight oscillations in level, caused the extreme variation in the sediments characteristic of the Laramie deposits.

These shifting conditions gave way to more stable ones in the early Tertiary. The high-grade clays were probably transported for long distances, probably from the Rocky mountains, which were then subject to decomposition and erosion, and were deposited in wide, quiet lakes in their present pure state. It is inconceivable that deposits so impervious should have been affected much, since their deposition, by circulating waters. The white, sandy fire clays, which generally underlie the more plastic ones, may be an exception to this statement. There are places, at Dickinson for example, where a ferruginous yellow sand grades into one of these pure, white, sandy clays. It may be that the iron minerals were leached out of the sand, and pure clay washed in from above.

The sediments since their deposition have suffered little change except from erosive action and remain to-day structurally simple, flat-lying beds of unconsolidated lignite, sands, and clays, much as they were originally laid down.

[1] U. S. Geological Survey, Bulletin No. 82.

# THE CUYUNA IRON RANGE.

NEWTON H. WINCHELL.

The Cuyuna Iron Range lies in Aitkin and Crow Wing counties, Minnesota, running S. W. and N. E. Owing to the rarity of rock outcrops and its isolation from the other well-known iron ranges, its geological structure and relations have been difficult to make out. The writer recently visited the eastern portion of the range, and, under the guidance of Mr. H. B. Ayers,

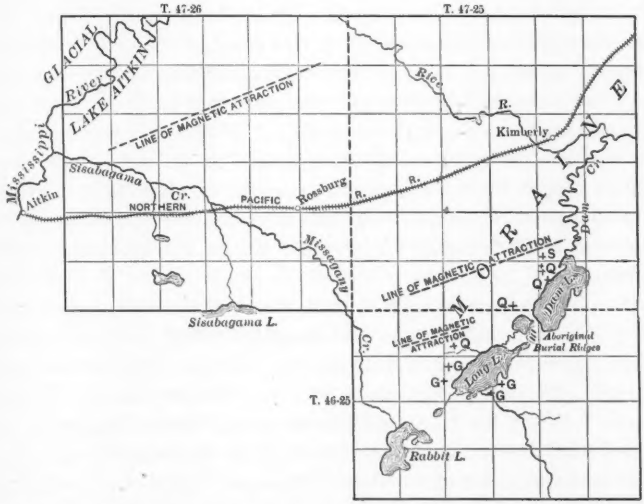


FIG. 64. Sketch map of the east end of the Cuyuna iron range. Scale approximately 3⅓ miles to the inch. Crosses indicate outcrops: *Q*, quartzite. *G*, greenstone. *S*, schist.

saw several exposures of rock of which no mention has been made heretofore, and examined some rock drillings. Mr. Ayers also furnished part of the data for the accompanying sketch-map, Fig. 64.

About fifteen years ago Mr. Ayers brought to the writer samples of quartzite from the north shore of Dam Lake, which were recognized as belonging to the basal quartzite of the Animikie, which lies below the iron ore of the Mesabi range. At a later date this quartzite was visited and examined by Mr. Warren Upham when he made the survey of Aitkin County for the state geological survey. Its location is shown on the map[1] prepared by him and accompanying his final report on that county. In the same report[2] the greenstone outcrops in the vicinity of Dam and Long lakes are described. They are considered to be parts of a great diabase dike of date later than the Animikie and probably cutting the quartzite of the region.

*The Quartzite at Dam Lake.*—There is no unequivocal evidence as to the direction of dip at this place. The outcrop which appears on sec. 35, T. 47–25, extends along the shore about 250 feet, but is so much broken or so massive that no bedding planes can be observed, although two small areas are certainly in place. By the occurrence of other outcrops and by the topography the dip is judged to be southeast, a supposition which would cause the supposed Animikie ore to lie under the waters of several small lakes that stretch along a N. E. and S. W. belt to the south.

At a point about a mile toward the southwest from this outcrop is another exposure of the same quartzite. This is on the S. W. ¼, S. E. ¼, sec. 34, T. 47–25. It is in the form of two smooth glaciated domes, about 25 feet in length and 15 feet in width. While the rock here has the same massive aspect there was found, fortunately, a separation plane marking the sedimentary structure with unmistakable clearness. This also conforms with the general known direction of glacial striæ with which the surface is covered, with the stoss side of broken knobs, and with the slope of the main surface, and shows a dip of about 25°, S. 30° E. Hence from Dam Lake to this place it is safe to conclude that the quartzite continues with about that dip and strike. About a mile and a half still farther the southwest, *i. e.*, in the

[1] Minn. Geol. Survey Atlas, plate lvii.
[2] Vol. IV., p. 36.

S. W. ¼ of sec. 4, T. 46–25, the same rock was struck in sinking a shaft, thus proving an extension along the strike of two and a half miles for this rock.

Back from the shore of Dam Lake, in the S. W. ¼, N. W. ¼, sec. 35, T. 47–25, a drill hole also reached this quartzite at such a distance from the lake as to show, in connection with the dip there, that the quartzite must have a considerable thickness, say 150 or 200 feet.

The place of this rock in the geological series cannot be mistaken. It has the grain, the color and the thickness of the basal quartzite of the Animikie. It contains frequent lavender or amethystine grains of quartz which are referable to the granite on which the Animikie lies. They have been derived from that rock by disintegration and sedimentary deposition, and the quartzite is consequently younger than the granite. The dip toward southeast, however, is contrary to what has been supposed, for the quartzite has been thought to be in the southern limb of a syncline in the Animikie, the western end of the Mesabi range being the northern arm, and the bottom of the syncline somewhere under the intervening country. This quartzite, on the northern limb of this supposed syncline, can be traced to the north end of Pokegama Lake, and if reports of land surveyors can be accepted it extends to the Little Boy River in Cass County; but of this western extension we have no details.[1] Why this quartzite appears in two parallel belts, both dipping to the southeast, cannot at present be explained. There are, however, several hypotheses that may be suggested.

1. It may be a westward continuation of that structure of the Animikie which is seen much farther northeast, *i. e.*, a succession of parallel faults running N. E., on the south side of which the rocks are raised much above those on the north side. The same structure is apparently repeated at the falls and dalles of the St. Louis River in Carleton County.

2. This area of the basal quartzite of the Animikie may be entirely isolated from the main body of the Animikie, and while dipping southeast at the points observed, it may rise along the

[1] See 18th Rep. Minn. Survey, pp. 14–16.

southern side of Dam and Long lakes, and, if it could be seen, it would there show a northwest dip. As greenstone of the Archean is known to occur on the southeasterly side of Long Lake, it would necessarily be a small and shallow synclinal basin, the southern arm of the basin being near the lake shore, or perhaps entirely under the water. If iron ore exists in this syncline it would be under the waters of Dam and Long lakes.

3. The line of strike of the quartzite from the Mesabi range may take a zigzag course in passing toward the southeast, and the dip may vary in consequence of the Archean topography upon which the sand was deposited.

In the absence of sufficient data, the manner of connection of this quartzite area with the quartzite at the base of the Mesabi iron-bearing rocks must be regarded as an unsettled problem.

*The Greenstone of the Region.*—At several places northwest of Dam and Long lakes, and at two points on the south side of Long Lake (S. W. ¼, sec. 10, and S. E. ¼, sec. 9, 46–25) are outcrops of greenstone plainly belonging to the Keewatin of the Archean. These outcrops are so near the quartzite outcrops that it is apparent that the greenstone passes non-conformably below the latter and hence that a great chronological break exists between the two formations, analogous to that between the rocks of the Mesabi range and the Archean. One of these outcrops, that in N. W. ¼, sec. 9, T. 46–25, was visited and drillings were examined from some test-holes that have reached the greenstone north of the quartzite. Although it has been called, at different places, " gray schist," " diorite " and " diabase," it is everywhere the rock which constitutes the main part of the Lower Keewatin. It is the great Kawishiwin greenstone, and it indicates that toward the north and west, under the drift, is spread a wide expanse of the Archean.

*The Iron Ores of the Cuyuna Range.*—The ores of the range were not personally studied. According to Mr. Ayers they are magnetic, and are distributed in N. E.–S. W. lines across the country northwest of Dam and Long lakes. See Fig. 64. These belts of attraction are separated by belts of non-magnetic country rock. They can be traced, with some interruptions, as

far west as Aitkin and Deerwood and even to the vicinity of Brainerd. At several places exploring operations have been started and many drill-holes have been sunk. In some cases a lean magnetic ore, associated with some hematite, has been found. The structure of the rock, with which the ore is parallel, is nearly vertical. It is probable that this structure is a combination of schistosity, due to pressure, and bedding planes, as is universally the case in the Archean rocks of northern Minnesota. The beds have been closely folded and compressed and the repetition of the magnetic belts in this region is likely to be due to repetition of the same bed, the crests of the anticlines having been truncated. On the other hand magnetic iron ore is known to run in narrow belts in the Keewatin, where it cannot be affirmed that the containing rock is clastic. In other words, there are, in the great greenstone formation of the Lower Keewatin, narrow magnetic belts, rather capriciously distributed, which run parallel with the general structure. These may be original in the igneous part of the Keewatin and may have acquired their position and present structure through other than sedimentary processes. When a great basic mass has suffered the vicissitudes through which the Archean greenstones have passed it may have acquired structures resembling bedding, and been so altered as to segregate the iron in belts which, when coincident with schistosity, would simulate an original fragmental banding. What portion of the iron ore in the magnetic belts of the Cuyuna range is due to fragmental accumulation and what portion, if any, to secondary processes, acting upon a basic igneous rock during a dynamic metamorphism, appears to be entirely unknown.

It is premature to attempt to give any stratigraphic succession. That all the ore as yet discovered, and all that is likely to be found, in the region of these magnetic belts, from the Mississippi eastward to Kimberly, belongs in the Archean, and hence is analogous to that of the Vermilion range, seems to the writer to be beyond question. This ore, therefore, so far as it has been discovered, lies structurally below the quartzite of Dam Lake,

and cannot be correlated genetically or chronologically with any ore overlying that quartzite.

*Volcanic Tuff.*—Those who are familiar with the reports of the Minnesota Survey will remember that the ore of the Mesabi range was stated to have been derived from the alteration of basic volcanic rocks. Such rocks were found to have been altered on an extensive scale, but still show traces of their original nature. In almost every place where, at that time, mining had been sufficient to expose the strata, remnants of the volcanic rock could be identified. The chief of these remnants was stated to be the granular soft hematite of the range, which was considered essentially an altered obsidian sand accumulated along a sea beach in the near vicinity of the volcanic vents whence it came. The greensand, which has been called *glauconite* and *greenalite,* into which the ore grades, was explained as an altered form of this volcanic sand, and it was shown that this fine sand grades into coarse masses and blocks, and that these blocks and masses, which are often found in the midst of the granular ore, are identical in material with much of the country rock that contains the ore.

It is not intended here to review the evidence for this hypothesis, as the full discussion is published in the Minnesota reports (Vol. V.). It has remained to the present to discover remnants of the unaltered volcanic rock to which reference was there made. The writer has not visited the Mesabi range since the field-work of the state survey was concluded, and has had no opportunity to reëxamine the field in the light of later developments, but has hoped some day to review this question.

Unexpectedly, however, some light has been thrown upon this matter by the discovery of a coarse volcanic tuff or breccia at the bottom of a shaft sunk by Pickands, Mather and Company, on sec. 8, T. 45–27, about eight miles east and three miles north from Brainerd. According to Mr. Jarchow, as stated to Mr. H. B. Ayers, of Kimberly, this tuff was about five feet thick and was called "conglomerate" by the workmen. It lies non-conformably on the vertical slates and ore of the Cuyuna range, and these are associated with more or less rock which Mr. Jarchow

called "greenstone." From the description, this rock seems to be a part of the volcanic tuff of the bottom of the Mesabi range. It is worthy of more full description. Specimens obtained through Mr. Ayers are unlike any rock hitherto found in Minnesota. While it appears like a conglomerate and contains numerous pebbles, up to half an inch in diameter, which seem to have been rounded by friction, it is composed wholly of volcanic material and its alteration products. It has a general hematitic red color. The matrix is fine-grained and in some places appears like brown quartz-porphyry or obsidian. This matrix is apparently composed of fine grains of the same kind as the pebbles. In some places are patches of hematite ore which appears to have been derived by segregation from the surrounding rock, but in most cases such hematitic rock has the shape of distinct grains or pebbles. Other pebbles are altered concentrically, having a center of some highly ferruginous mineral, or group of minerals, surrounded by rings of different composition but heavy with iron ore, the outermost coating being loose and limonitic. Some pebbles are altered uniformly from circumference to center. These were undoubtedly originally glassy. Some few are amygdaloidal. The most common and striking feature of the pebbles is their concentric alteration and the tendency of the iron to gather at one side or in the center.

Whether this rock belongs to the basal portions of the Mesabi range or to some part of the Keweenawan is problematic. It is far beyond any known extension of the Keweenawan, but it is in the area where the Mesabi is supposed to be present. No such rock has been discovered within the Keweenawan, though it is allied to the fine conglomerates of the Manitou part of the Keweenawan. On the other hand, it seems to accord with the hypothesis advanced to explain the origin of the Mesabi ores and its mode of alteration is identical with that of the pebbles and small grains that have been altered to form the Mesabi iron ore. If it has, as reported, a thickness of five feet and lies non-conformably on the ores and slates of the Cuyuna range, it cannot be considered a drift boulder, but must be some part of the unaltered basal strata of the Mesabi range.

# COPPER DEPOSITS IN THE BELT FORMATION IN MONTANA.

M. COLLEN.

Two distinct series of sedimentary formations occur in the Rocky Mountain region of central and northwestern Montana, between the Archean complex and the basal beds of the Cambrian. They are separated by great unconformities both from the Archæan and from the Cambrian. The latter carries a fauna of Middle Cambrian type. These two sedimentary series are separated from each other by a distinct and well-marked unconformity. Both series are fossiliferous in the Little Belt and Big Belt mountains.

The lower series, which consists of dense quartzites, dark-colored shales, and thinly-bedded, shaly, almost black limestones, attains a thickness of several thousand feet and was intruded before the upper series was deposited by dikes and sills of an igneous rock, resembling quartz-porphyry.

The dark-colored limestones, which have a fetid odor when crushed, contain forms that resemble *Favosites* to a remarkable degree, as well as several other obscure fossils, that show unmistakable evidence of their organic origin. These curious and undetermined organic forms are extremely abundant in the Newland limestone formation, and often make up the whole thickness of beds.

Resting upon the eroded surface of this lower series, with marked unconformity, occurs an upper series, consisting of basal conglomerates, quartzites, dark-colored shales, carrying crustacean remains and worm-trails, gray shales, limestones, gray shales, thin-bedded, dark limestones and finally green shales.

This upper series, which attains a thickness of many thousands of feet, was intruded by dikes and sills of diabase in pre-Cambrian times, but is nowhere intensely metamorphosed, save near these diabase intrusions, which occur throughout the series, and

often attain great development. The basal sandstone of the Cambrian (Flathead sandstone) rests unconformably upon this upper series. The basal beds of the upper series derived their material principally from the lower series and not directly from the Archæan. They are beautifully exposed in the cañon of Deep Creek and thence southeast to Greyson Creek, and stand in a nearly vertical position. At this locality there is a true basal conglomerate resting upon a bed of black calcareous shale. It is made up of fragments of dark-colored limestone, quartzite, slate, sandstone, indurated shale and igneous rock of a granitic texture. Above it lie dense quartzites, siliceous shales, conglomerates, quartzite and other conglomerates. About one thousand feet of quartzites and siliceous shales is here exposed with several interbedded conglomerates, formed of angular and subangular fragments, of very heterogenous material, which strongly suggests a glacial origin for these beds. A few miles southeast of this locality the conglomerates contain fragments derived from the underlying Newland limestone, some of which are ten feet in diameter and contain organic remains of a *Stromatopora*-like form. These basal beds are locally gold-bearing in the Big Belt Mountains and may have furnished the gold for the extremely rich placers of Diamond City. The underlying Newland limestone, which was intruded by dikes and sills of quartz-porphyry (?) before these conglomerates were formed, is also gold-bearing. Every gulch in the Big Belt Mountains which cuts down into the basal conglomerate, or into the underlying Newland limestone, carries placer gold.

Immediately overlying these basal quartzites and conglomerates are beds of black slate or shale, in which Mr. C. D. Walcott found the fragments of Crustaceans, worm-trails, etc., described in his bulletin on the fossiliferous pre-Cambrian formations.[1]

The limestones of the upper series are entirely different from those of the lower series and seem to have been formed in rather shallow and quiet waters. They have a remarkably knotty and crinkled appearance; are of a dark gray or black color, give out a fetid odor when crushed, and occur in thin beds or massive

[1] Bull. Geol. Soc. Am., vol. 10, 1899, pp. 199–244.

beds throughout a great vertical extent of the series. Some of them are probably of analogous growth, while some are made up of what appears to be calcareous sponges, of a *Stromatopora*-like form. Some of the latter contain numerous flakes of graphite in their interiors and certain beds are impregnated with chalcopyrite and chalcocite, which may be altered to malachite. The *Stromatopora*-like forms grew upon the mud of the sea floor, singly and in groups, like a bed of mushrooms. They were globular in form and were composed of innumerable very thin laminæ concentrically arranged. The interspaces were probably occupied by the jelly-like substance of the organism. When mud was deposited upon these fossil forms they were crushed and compressed.

The upper series contains a great thickness of red shale (Spokane shale). These red beds outcrop over a wide extent of the Rocky Mountain region in Montana, and form many of the high peaks of the various ranges. They vary in texture from shales to quartzitic sandstone, and attain a much greater thickness in the main range of the Rocky Mountains and in the Swan range than in the Belt Mountains. These same beds may be seen near Missoula, Montana.

At many different places throughout this whole territory the red beds carry copper ores, sometimes in veins and sometimes in bedded deposits. These copper deposits are almost always associated with intrusions of diabase. Where the diabase is thoroughly decomposed the copper ores are often abundant, but where the diabase is not much altered, the copper occurs generally only as a green stain in the joints of certain gray shales that are interbedded with the red shales.

In the Big Belt Mountains, in the Little Belt Mountains, Spokane Hills, Newland Creek Hill and at many places along the Big Blackfoot and South Flathead rivers such deposits of copper are found. Some of them are of great promise. In some cases the diabase seems to be absent, but it can generally be shown that erosion has removed masses of this rock from such localities.

As to the genesis of the copper ores, I believe that the copper was originally contained in minute quantities, in the diabase.

Subsequent orogenic forces fractured the pre-Cambrian rocks and opened passageways for the circulation of ground water, which leached the copper from the diabase, together with some other of its original constituents. Where faults and fissures occur the copper was deposited along them; especially where they cut gray or red shales or limestones, carrying some organic matter. In the series of red shales underlying a thick sill of diabase, copper is often found impregnating strata of limestones or green shales, but it is generally less abundant in the quartzitic beds. In the fissure veins, traversing the red beds, the relative abundance is generally as follows: milk-white quartz, siderite, copper sulphides, galena, rhodonite, barite, and calcite.

Throughout this region, then, and in widely separated districts the upper pre-Cambrian series contains copper deposits associated with diabase. Wherever later intrusions and faulting induced a more vigorous circulation, a more thorough alteration of the diabase took place, resulting in greater concentration of the copper. It is possible that these later intrusions may have furnished the deposits with their quota of copper, and perhaps also with other metals.

WHITE SULPHUR SPRINGS, MONTANA.

# POSSIBLE OBLIQUE MINOR FAULTING IN ALASKA.[1]

LAWRENCE MARTIN.

In the Yakutat Bay earthquakes of September, 1899, it was found that the seismic disturbances were due to movement along definite fault zones bounding a series of blocks whose edges were differentially tilted, resulting in a series of remarkable changes of level of the land.[2]

The blocks jostled upward along old fault lines in this renewal of growth of the St. Elias Range were themselves broken, as fresh scarps in a number of localities indicated, and on Gannett Nunatak a series of remarkably perfect step faults were observed. These we have already described[3] and it is in these minor faults that the possible oblique movement, with which this paper is concerned, has taken place.

In review of the topographic conditions it should be stated that a strongly-glaciated rock hill rising directly out of the fiord and made up of highly-inclined gneisses and schists is crossed by a score or two of parallel faults, usually with vertical hade, the height of the scarps varying from one inch or more to eight feet, but the average remaining under one foot and two-fifths. The movement has usually been parallel to the schistosity and the southwest is usually the upthrow side. A complete cross-section of all the faults along one line, measured under the direction of Professor Tarr in 1906, showed 29 scarps, 26 of which had an upthrow on the southwest side aggregating 30½ feet, 3 having upthrow on the northeast side aggregating 12 feet, so that the total absolute displacement along this line is 18½ feet. Along the adjacent shoreline there was practically no change of level.

[1] Published by permission of the Director of the U. S. Geological Survey. I am indebted to Professors C. K. Leith and R. S. Tarr for many suggestions in connection with the problem here discussed.

[2] Tarr and Martin, *Bull. Geol. Soc. Am.*, Vol. 17, 1906, pp. 29–64.

[3] Tarr and Martin, *Bull. Geol. Soc. Am.*, Vol. 17, 1906, p. 50 and Plates 20 and 21.

It has been conceived worthy of consideration, though the facts have not yet been tested in the field, that the movements along the fault planes in these Gannett Nunatak faults were not vertical but inclined.

As previously stated, these are minor faults. They are due to adjustment of strain in a larger fault block. The units in this larger block were of unequal size and strength. One of the units was the band of schists which make up this part of the nunatak. The adjacent units were more massive granites and gneisses. When the whole body of units making up the block was jostled by the differential tilting of the adjacent blocks, during the larger faulting which caused the earthquakes, the diversified rock units responded or resisted as their nature allowed. Granite, perhaps, adjusted itself to the new strain by slipping along minute planes, gneiss by similar movement, and each, being rigid, gave an added strain to the adjacent schistose unit. Held thus between rigid boundaries, the schist, following the direction of least resistance, slipped along its cleavage surfaces like a pack of cards. As the schist stands nearly vertical, relief would come by some sort of an upward movement, even though the strain were applied laterally in a horizontal or an oblique plane and not from below. The faulting, with a total absolute displacement of at least 18½ feet, would on this supposition not be due primarily to uplift; and this conclusion is supported by the lack of evidence of change of level along the coast immediately adjacent to the nunatak. The marine register is a very delicate one, and change of level due to as great uplift as that indicated by the minor faults could hardly fail to leave a definite record, as it did practically everywhere else in the region where change of level took place.

In the California earthquake of 1906 it was established that the faulting was predominantly a horizontal movement.[1] F. L. Ransome has recently[2] called attention specifically to the possibility that horizontal movement along a fault plane might produce an apparent vertical displacement, and on this basis the

[1] Preliminary Report of the State Earthquake Investigation Commission, p. 10.

[2] Economic Geology, Vol. 1, 1906, pp. 777–787.

nomenclature of faults has been subsequently discussed in this journal.

On the Gannett Nunatak the faults traverse a hillside and especial attention is, therefore, called to this as a case where an observable, apparently vertical displacement might actually have been produced by movements in a horizontal plane. In this case the hill would be thought of as broken into northwest-southeast strips, each strip being moved southeast with respect to its northeast neighbor, so that the hill slope might be said to no longer fit. Such horizontal movement would produce a similar distribution of faults to that actually found, *i. e.*, successive normal faults with upthrow on the southwest side, so that in going down hill one constantly kept going up steps. The expectable exceptions of faults with apparent upthrows (scarps) on the northeast side, due to failure of a strip to slip in the normal direction, and short cross faults, due to breaking of the long narrow strips, are found.

If this were all, the case might be considered a very pretty one, for it could be absolutely proved by going to the other side of the hill where the opposite distribution of upthrows should be found. In the observed case the investigator goes up steps as he goes down hill. If on the other side of the hill he went down steps as he went down hill, the nunatak could be definitely said to be broken into strips along which horizontal movement had caused the slopes to no longer fit, resulting in apparent, but false, vertical displacement.

Unfortunately the opposite side of the hill shows no faults at all. The larger scarps extend up to the crest and die out. On the hypothesis here considered one of two things may have happened: (1) Either the schists, along which movement is so easy, have been replaced by other, more elastic, or massive, rocks; or else (2) there has been oblique movement, parallel to the surface of the unfaulted hill slope (Fig. 65).

We cannot assume that the schists extend to the unfaulted side of the hill and that the displacement on the opposite side is the result of vertical movement, for in that case there is no excuse for the failure of both hill slopes to be faulted alike. Moreover,

the lack of evidence of change of level on the neighboring shore, as already stated, precludes the idea of uplift here. It cannot be held that the movement was entirely horizontal, for there are fault scarps on the very top of the hill.

The alternate hypotheses are either vertical uplift or subsidence of a larger block, with differential movement along the layers, dying out in short distances as a result of adjustments and tilting. If there had been such movement it is strange that here,

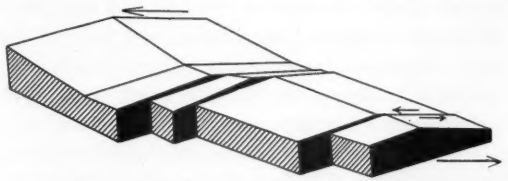

FIG. 65. Diagram illustrating oblique faulting with movement parallel to hill slope on right, producing scarps on the opposite slope and along the crest. Such movement would effect essentially no change of level in a shoreline on the right.

in one of the few places in the fiord where there is no evidence of change of level along the shore, we should find the best cases of differential movement in the entire region. If, on the other hand, the vertical throws are the result of oblique movement due to differential horizontal strain the absence of proof of uplift along the shore is readily explained.

Unfortunately this idea was not suggested on the ground and cannot therefore be tested until further observations have been made. Oblique movement seems to be the most rational hypothesis for the facts discovered; but the case has been discussed thus fully here not so much to prove this particular case as to illustrate that an observer cannot safely infer vertical movement because he finds a scarp. He may have either horizontal or an oblique movement. Unless he has a whole faulted hill for study he would have to depend on examination of the fault-plane surfaces and see the direction of slickensides, before he could come to a decision. This should be done for the faults of Gannett Nunatak.

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# PRECIPITATION OF COPPER FROM CHLORIDE SOLUTIONS BY MEANS OF FERROUS CHLORIDE.

GUSTAVE FERNEKES.

During the winter of 1906–07, Dr. A. C. Lane, State Geologist of Michigan, requested me to make analyses of the waters of the Lake Superior copper mines for the purpose of determining whether these waters could in any way be connected with the genesis of the copper deposits in that region.

A series of analyses was made upon samples from various mines from depths ranging from 800 to 5,000 feet. It appears from these analyses that the waters are more or less concentrated solutions of calcium chloride, sodium chloride and sodium bromide, with traces of sulphates. Furthermore the concentration of these solutions increases with the depth. Upon reading an account of the very interesting experiments of Doctor Stokes[1] in which metallic copper was precipitated from copper sulphate solution by means of ferrous sulphate, it occurred to Doctor Lane that similar results might be obtained when the chlorides instead of the sulphates of the above metals were used.

Preliminary experiments carried out according to the method of Stokes, however, gave negative results, *i. e.,* no copper was deposited. The cause of the failure is due to the fact that metallic copper is soluble in hot dilute hydrochloric acid, whereas dilute sulphuric acid which was set free in Stokes' experiments has absolutely no effect upon the copper. The following reactions which have been published by Lane[2] with an explanatory letter show the change which takes place.

1. $2FeCl_2 + 2CuCl_2 = Cu_2Cl_2 + 2FeCl_3$.
2. $2FeCl_2 + 2CuCl = 2Cu + 2FeCl_3$.

[1] This journal, Vol. I., 1906, p. 644.
[2] *Science,* Vol. XXV., p. 589.

The ferric chloride is then hydrolyzed according to the following well known reaction:

3. $FeCl_3 + 2H_2O = Fe(OH)_2Cl + 2HCl$.

Reaction 3 takes place at high temperatures and fairly dilute solutions. The reactions which take place in the experiments of Stokes are similar to the above. As he used the sulphates instead of the chlorides, free sulphuric acid instead of hydrochloric acid was formed.

As only traces of sulphates were present in the waters examined, and they are rare in the rocks and minerals of this region,[1] more careful attempts to precipitate the copper from chloride solutions seemed justifiable.

To make the precipitation of copper possible according to the above reactions, the hydrochloric acid must be constantly neutralized. This neutralization can be brought about by the carbonates or silicates of calcium and sodium. Calcium hydroxide was first tried, then calcium carbonate and finally calcium silicate in the form of the mineral wollastonite. The experiments were successful, the copper being deposited in from ten to fifteen minutes heating at 200° C.

Complete precipitation required a somewhat longer time. It is evident that the more soluble the neutralizing mineral is in hydrochloric acid the more efficient it is for rapid neutralization and consequent precipitation of the copper. It also seems probable that we would be able to obtain crystalline copper more readily if a slower neutralization took place than in the above experiments where in fact the copper came down in a fluffy condition.

At this point Doctor Lane suggested the following minerals, common in this region, which may have taken part in the neutralization of the free acid: labradorite, prehnite, laumontite, datolite, analcite and pectolite. Of these minerals the first three were present in the rocks before the copper deposits were formed and the last three are closely associated with the metal. The first four minerals were tried but positive results were obtained only with prehnite and datolite. Since the conditions of the

[1] A. C. Lane, *American Geologist*, Vol. XXXIV., 1906, p. 309.

experiments, as finally carried out, were slightly different from those described by Stokes, it may be well to mention a few of the modifications introduced. Instead of employing a metal bath as did Stokes, an ordinary sand bath was used. The thermometer was placed alongside of the sealed tube containing the solutions. As explosions are not frequent this arrangement is perfectly satisfactory. The total length of the tubes employed was also greater, being about eighteen inches. The upper limb of the tube was surrounded by a water jacket. The temperature of the lower limb ranged from 200° C. to 280° C. The material was introduced into the tube in the following order: first about five grams of the neutralizing mineral, finely ground and freed from possible admixture of copper by treatment with nitric acid; then 0.2 grams of copper chloride; and finally a solution of ferrous chloride, containing an excess over that required to precipitate all of the copper. A few crystals of potassium bromide were also added. The solution which was always slightly acid, due to the ferrous chloride, was then almost neutralized by the addition of sodium carbonate, filled to the top with water and sealed.

In the case of prehnite, perfect circulation of the liquid above the mineral continued for about five hours when heated to 200° C. At the end of this time the basic iron salt formed in the reaction covered the small surface of the exposed prehnite to the height of two to three centimeters and consequently further action proceeded very slowly. Occasional cooling of the lower limb of the tube was therefore resorted to and by this means the solution was drawn back into the mineral, constantly exposing new surfaces. The tubes were heated intermittently for ten hours during the day. The heat was removed in the evening and again applied the next morning. After heating the solution and prehnite in this manner for five days an explosion took place at about 250° C. A portion of the side of the tube about five centimeters from the bottom was blown off, leaving a fairly hard cake underneath. On examining this cake of mineral with a small hand lens, it was found to be interspersed with shiny particles of crystalline copper. A few chemical tests were made.

The particles were soluble in nitric acid with the evolution of brown fumes. They were insoluble in dilute hydrochloric acid, which fact distinguished them from cuprous oxide, and they precipitated metallic silver from neutral silver nitrate solution. The prehnite had become much darkened and the particles of the mineral were stained red in places with iron oxide.

Datolite was acted upon in a similar manner for six days, at the end of which time minute crystals of copper could be detected throughout the mass of the mineral.

Experiments with laumontite and labradorite have up to the present time been unsuccessful and lack of time prevents me from carrying out more extensive researches in this direction.

It is not the object of this paper to draw any geological conclusions, especially as so few experiments have been performed. Nevertheless the work may be of value in reference to the genesis of copper deposits in the Lake Superior region. It is possible that hot solutions of copper and ferrous chlorides acted upon each other with the liberation of free hydrochloric acid as in the foregoing experiments. The hydrochloric acid acted upon the surrounding rock, consisting principally of calcium and sodium silicates, and a neutralization was effected. Simultaneously with this neutralization the copper was precipitated. Calcium and sodium chlorides were left in solution (mine waters), and silica was precipitated as quartz. Possibly the temperatures and pressures were far higher than those in the experiments.

From these considerations one might expect that the relation of the calcium to the sodium would be the same as that existing in the original igneous rock. No such relation has thus far been determined. The analyses differ materially with the locality and depth of the samples.

The following analyses of typical mine waters show the relation of sodium to calcium with varying depths, the results being given in grams per liter:

It may be seen that the sodium in the upper level of the Centennial mine is in excess of the calcium, whereas in the lower level the quantity of calcium is about six times that of the sodium.

ANALYSES OF MINE WATERS.

| | I. | II. | III. |
|---|---|---|---|
| Cl | 17.74 | 5.780 | 3.549 |
| Ca | 8.75 | 1.880 | .880 |
| Na | 1.49 | 1.584 | 1.287 |
| Br | .224 | | |
| $SO_4$ | .0123 | | |
| Total | 28.21 | 9.244 | 5.716 |

I. From Quincy mine, No. 6 shaft, 53d level. Depth about 5,000 feet.
II. From the 20th level of the Centennial mine. Depth about 2,000 feet.
III. From the 11th level of the Centennial mine. Depth about 1,100 feet.

Although it is generally true that the calcium in the volcanic rock is considerably in excess of the sodium yet no average of a great number of analyses is available. Results of analyses of traps are cited in volume 6, part 1, of the Michigan Geological Survey. The amount of CaO varies from 7 to 10 per cent., and the NaO from 3 to 5 per cent. Further work along this line will be carried out when time permits.

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# DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, South Bethlehem, Pa. The full name of the author should be attached to all communications.

## *THE FAULT PROBLEM. I.*

*Sir:*—In so far as this discussion[1] may be regarded as a step toward a present classification and nomenclature of faults, I have little sympathy with it. In my judgment the time is far from ripe for permanent classification and nomenclature. We need to know very much more about the processes of faulting and their place and significance in the dynamics of the earth before we can wisely harness our ideas with technical terms. The initial strain of plaint that our predecessors have trammelled us with premature and ill-chosen classes and names has for its logical response a forbearance on our part from further imposition of the kind on our successors; perhaps also it suggests an effort to free ourselves from our hamperings by dropping embarrassing terms, and by de-technicalizing such as it seems best to retain. It does not help in serious work to still further technicalize what are already a hindrance so that, for instance, one and the same faulting act shall be made to give a "normal" fault on the east end of a block and a "heave" fault on the north and south sides of the same block; nor is it well to assign hyper-technicalized senses to those who do not use them. The terms "normal" and "reversed" are confessedly an infelicitous inheritance from an ill-considered nomenclature, but usage sanctions their employ-

[1] This journal, Vol. I., No. 8 (Ransome); Vol. II., No. 1 (Jaggar); Vol. II., No. 2 (Spurr, Fairchild); Vol. II., No. 3 (Willis, Reid, John A.).

ment and they may properly be given broad generic senses, to include, on the one hand, the faultings which owe their existence and characteristics to the dominant influence of tensional or relaxative conditions, and, on the other, those which spring from conditions of compression or thrust. In both these the horizontal movement, in its several phases, is the most significant factor, dynamically, and the larger the problem and the broader the point of view, the more vital does the horizontal element become, because it is the most distinctive component of the action of gravity to which all common faults owe their ultimate origin. We go much beyond most of our colleagues in giving importance to the horizontal element in faulting, as will appear in the course of this paper and as is indicated in our Geology (Vol. I., p. 522, Vol. II., pp. 131–132, 233–236, Vol. III., pp. 519, 528), but we have supposed that all these extensions, however much beyond the conventional views, were legitimately included under the groups named normal and reversed, using these terms in their generic senses, as sanctioned by good usage. We do not entertain those ultra-technical limitations of these terms, especially those of a geometric nature, which cut out their main meanings, however convenient these geometric aspects may be by way of illustrative definition. Very probably the generic groups will, when fully worked out, give grounds for distinguishing some rather definite species and varieties, but there will undoubtedly remain an extensive tailing out of derivatives, equivocals, and incidentals which it would be folly to specially classify and name. As everything in nature grades into something else, a perfect definition is an idle hope, and a complete classification and nomenclature a fruitless dream. The modern scientist must recognize the inevitable consequences of gradation, and content himself with definitions, classes and names which only tell the main truth. In any limited statement he must read between the lines the implications of gradation from that which is defined, classed and named into that, on one side or another, which is undefined, unclassified and unnamed; and this is peculiarly true of a phenomenon that is but a phase of another phenomenon, as faulting is but a phase of deformation.

VERBAL AND TECHNICAL DIFFERENCES.

If we pretend to be precise in details, the treatment of faults is trammelled from the outset by the fact that we are not quite at one as to what constitutes faulting. By some it is defined from the viewpoint of the fissure; by others from that of the formation; by still others from that of the block; to some it is the result of a movement only, to others it includes the break precedent to the movement; by some it is an offset of beds or their equivalents, by others it includes parallel movements of the beds without offset. A definition more complete than most is as follows: "A severance of the continuity of a body of rock by a break through the mass, attended by movement on one side or the other of the break, so that what were once parts of one continuous stratum are now separated" (Century Dictionary). But even this does not fully define a fault, for a break and a separation of the once continuous stratum by a simple pulling apart of the dissevered portions, resulting in a fissure, is not regarded as a fault. Nor is the formation of its own fault-plane by breakage usually regarded as a necessary feature of a faulting action when a previous break is available, and yet it is essential to a complete dynamic conception and is wisely made a part of the definition. The movement of a block parallel to the strike of one of its bounding planes is classed by some as a fault, as done by Ransome in the initial article of this series, and failure to so recognize it is made the basis of some of his criticisms; but by others, as by Suess, such a movement is distinguished from a fault, and called a "Blatt."[1]

Even if we make the break of the strata an essential part of the faulting, we are not altogether free from possible confusion, for there is a radical difference between a break followed at once by a dislocation due to the same stress, and a break made by one stress, followed at some later date by a dislocation due to a wholly different stress. The first is the case which systematic writers usually have in mind when they are setting forth the

[1] "Das Antlitz der Erde," Vol. I., p. 159. Blatt is translated "flaw" by Sollas, Vol. I., p. 120, "The Face of the Earth" (authorized translation), 1904.

dynamic nature of faulting, and it is clearly the only complete and typical case, as the whole effect involved in faulting is then made the work of a single differential stress expressing itself completely in breakage and movement. In the latter case the faulting phenomena combine the effects of an accidental sequence of an earlier and a later of two or more distinct differential stresses.

We seem to be further hampered by some instability of view—doubtless quite unconscious—as to whether faults are natural phenomena solely, or are also ideal and artificial; at least we make blocks of artificial forms, traversed by artificial planes, possessed of artificial freedoms of movement, and acted upon by artificial couplets of forces, take the place of natural formations, structures and forces without being very careful to show that they truly represent natural properties and processes. It goes without saying that artificial blocks may be moved relative to one another without compression or tension, and in almost any way, if we so elect. It is quite obvious that if we select blocks that have free faces and free edges, and subject them to sharply defined artificial stresses, instead of the distributive ones of nature, they may break and slip in ways not likely to be repeated in the unfractured crust of the earth, free only at the surface. In short, given free selection of conditions and forces, almost any result, consistent with mechanics, may be brought forth. When one samples a laminated bed of peat, marl, or clay with a common auger, he takes out his specimen by an artificial sort of faulting, but it is a spiral warp not easily formulated under the most reformed system of classification and nomenclature.

### DIVERGENCIES AND SECONDARIES.

It is obvious therefore that if we are to keep reasonably free from the interminable tangles of the artificially possible we must proceed with circumspection. Scarcely less is it necessary to proceed with care if we are to avoid the intricate jungle of natural divergencies, fortuities, and abnormalities. Let us therefore, before proceeding to serious discussion, glance at some of these, and see if we are not agreed that they should be laid on

the shelf as incidentals and neglected in a systematic treatment of essentials.

If the plane of a faulting movement emerges at the surface through a talus slope, the individual movements of the talus blocks over one another will be derivatives or divergencies from the main fault movement, and will be of the most varied kind. Not only will almost all forms of sliding of surface planes over one another be present, but almost every phase of rotation, with almost infinite combinations of the two. If one were to make these the subject of study and regard them as cases of faulting, it could be said with eminent truth that the direction of fault motion may form any angle with the strike of the faulted blocks, or any other base of reference. But it is obvious that the innumerable block-faces have only an incidental relation to the real fault plane which cuts through the talus pile. If attention were centered on the faultings of the talus blocks—if these are to be called faultings at all—the essential faulting might be wholly overlooked.

If for the talus pile we substitute a tract of broken beds, similar divergencies will arise, though in a more restrained way. The broken blocks will slide or rotate upon one another in the lines of least resistance, resulting in displacements in various planes and directions more or less divergent from those of the primary actuating movement. Studied from the point of view of the individual block-faces, with little doubt, "the direction of motion may form any angle with the horizontal line representing the strike of the fault," if the strike of the fault is taken from the plane of movement of the particular block in question. But the strike of the primary or true fault is quite another thing, and it is this which is sought by the incisive student who wishes to reach the heart of the matter.

When, in a case of this kind, the previous breaking up of the beds was attended by faulting as well as fracture, the complications that may grow out of the superposition of the divergencies from the new faulting upon the dislocations of the old faulting, are liable to rise to forbidding intricacy. Where the blocks formed by the earlier action are few and large, the divergencies

are simpler, but are all the more liable to be mistaken for primary movements.

When the working geologist, by limitation of exposure, is permitted to deal with only a small part of the total phenomena, he can do little more than record the observable geometries of his fractional case. The rules for interpreting primary or typical faulting, even if they were fully and surely known, would be very liable to fail to fit the case, if it were a divergent one. But it is a serious error to confound the defective phenomena of such fractional cases, possibly obscured by adventitious divergencies, with the typical phenomena of primary faulting in which all the features are direct expressions of a normal dynamical process.

### ACCESSORY FAULTING.

Before turning to this typical faulting, we may do well to put ourselves on further guard against sources of misconception. Besides the divergencies from primary action that may arise from a previously dissevered state of the rocks, and from the sequence of one stage of faulting upon another, there is need to note, even in a typical case, the difference between the primary and the accessory phases of faulting, and to put the accessory faultings in their true place, if we would clearly grasp the central phenomena.

If a portion of the shell of the earth be folded along a given tract and a certain section of this be overfolded, and a part of this overfolding passes beyond the cohesive strength of the folded beds, fracture and overthrust-faulting ensue. In a typical case the overthrust of the beds is likely to be greatest at some median point and to die away from this to zero at the limit of faulting on either side. Seen in plan, the fault-sheared flap of dislocated rock is crescentic; its middle portion has been thrust forward more than the flanking portions. If this difference of thrust be sufficiently great, fractures may be developed more or less parallel to the line of movement and the rock on the side of the greater thrust may be pushed forward more than that on the side of the lesser thrust, though both may be moving forward as parts of the common overthrust. In such a case the edges of

the two portions move differentially in the same direction. Striæ parallel to the edges may be developed and the resulting dislocation may, if we please, be called a "fault," and specially designated "transcurrent," as done by some authors, or may be differentiated from faults and called a "blatt" or "flaw," as done by others, or we may simply state the facts and give no name.[1] In any case, it is but an accessory phenomenon, and ought not to be considered alone in dynamic treatment, if it is possible to associate it, in its proper subordination, with the dominant action from which it is a derivative.

Dislocations of this kind are of course liable to be confounded with special cases of successive faulting where an old fault plane serves a new fault movement in lieu of a new fracture plane proper to itself. The recent horizontal movement on the old San Andreas fault-plane in California, may belong to this latter type and it may be altogether an error to refer it to the former class; but without a critical knowledge of the facts of the case, it is unsafe to venture an opinion. We may well wait for light on this case from the earthquake commission which now has it under study. It is quite proper, however, to challenge the citation of this interesting instance as though it were an unquestionable illustration of a genuine "transcurrent" fault, until its dynamics are worked out, and it is shown to be something other than an instance of the divergent easing of a stress which, by itself alone, undirected by the old fault, might have expressed itself quite differently.

In such a folding action as we have been considering, there is every reason to suppose that there was present a stress longitudinal to the fold in addition to the effective transverse one which produced the fold, for a segment of the crust is normally a dome, and a natural stress that tends to folding in one direction is presumably accompanied by a complementary stress at right angles to that direction. Usually, as in the case in hand, one of these stresses has an advantage over the other and takes precedence in producing folding. When, however, this dominant thrust has

[1] These do not appear to be the only cases to which these terms are applied nor is it clear that they have been used altogether synonymously.

eased itself by forming the fold, by pushing it over, by fracturing it and by thrusting the upper part forward, the resistance of this portion to the complementary thrust is reduced and this thrust may then give origin to faulting. By taking advantage of the fault plane already developed, it may force a transverse movement upon the previously faulted beds. Such action is in a sense accessory, and in a sense secondary, and is subject to divergencies from a normal expression through the influence of the fracture plane already developed.

In using the descriptive terms, accessories, secondaries, divergencies and so forth, I am not proposing names, but merely trying to clear away the adventitious features of faulting to get at the essence of the subject. An exhaustive analysis would show more of these accessory, derivative and adventitious cases, but these suffice for present illustrative purposes.

### THE GEOMETRIES OF FAULTS.

It has been hinted that the geneses and the dynamics of faults may well be held in abeyance until we have a firmer hold upon them, and that the geometries involved be given precedence. While the geometries without the geneses and the dynamics are not unlike the play of Hamlet with not only Hamlet but everything else, except the cast and the stage properties, left out, a full treatment of the geometries, as such, would be helpful in its way; but, if carried out strictly on its own lines, it would depart widely from the current eclectic method of treatment and might be found ill-suited to replace this, defective as it is. A discussion of the geometries of faults by themselves is embarrassed by the fact that faulting is only one phase of the changes of form which sections of the earth's shell undergo. Faulting grades into and out of other phases of deformation, and these must, therefore, enter into any comprehensive treatment of the case as it occurs in nature. We may, however, assume, for purposes of elementary treatment, ideal cases in which all changes of form take place by faulting. For this purpose also we may ignore such changes of volume as arise from the gaping of fissures, on the one hand, and from compacting by pressure on the other.

In such an attempt at geometric treatment we may not find a more effective key than in the law of constancy of volume. Whatever is lost in one dimension must be made good in some other dimension. The essence of the geometric problem, as such, is, therefore, the method by which these compensations are secured. If a block or section of the earth's shell is so deformed that its two horizontal dimensions are extended, its vertical dimension must be reduced; if the horizontal dimensions are reduced, the vertical must be increased, and so on through the possible combinations of the three dimensions, which includes cases in which one or even two of the dimensions are unaffected. A simple case adapted to illustration is that in which one horizontal dimension remains fixed and the remaining horizontal and the vertical dimension appear as variants in the plane of the paper. The reciprocal relations of these two dimensions may be illustrated by Fig. 66, where the increase in horizontal dimension is repre-

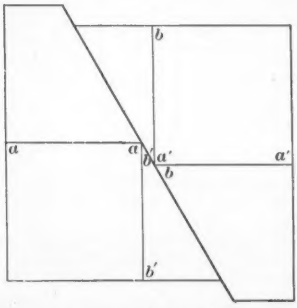


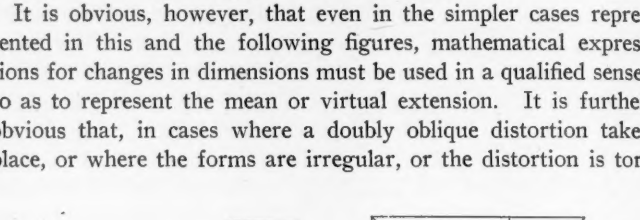

FIG. 66. An illustration of the reciprocal effect of faulting on structure lines lying in complementary directions, one vertical and one horizontal, the remaining horizontal dimension being unchanged.

sented by the gap between *aa* and *a'a'*, and the reduction[1] of the vertical dimension is represented by the overlap of *bb* and *b'b'*. The gap in the one case and the overlap in the other *are but complementary expressions of the same act,* which may be said to be thus recorded *in double entry. Both expressions mean pre-*

[1] It will be seen from the figure that this is reduction in a qualified sense.

*cisely the same ultimate thing,* though directly opposite in their individual aspects; and each is evidence of the other. When all three dimensions are changed, the sum of the extensional components, usually expressed in one or two of the dimensions, is the complement of the contractional components, usually expressed in the remaining one or two dimensions.

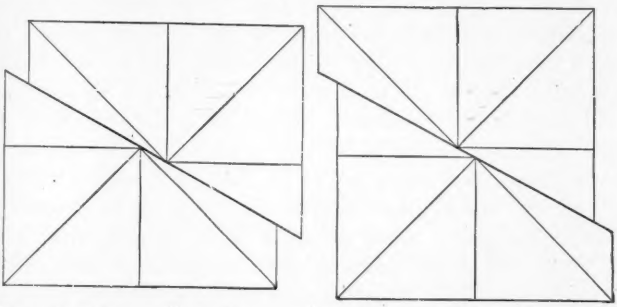
It is obvious, however, that even in the simpler cases represented in this and the following figures, mathematical expressions for changes in dimensions must be used in a qualified sense, so as to represent the mean or virtual extension. It is further obvious that, in cases where a doubly oblique distortion takes place, or where the forms are irregular, or the distortion is tor-



FIGS. 67 and 68. Illustrating complementary gaps and overlaps in cases usually interpreted as normal and reversed, respectively.

tional or rotary, the evaluation may be difficult, but still it remains clear that, if gaps are found in one set of dimensions, overlaps which are potentially equivalent must be found in the other. To express these, ideal structure-planes lying in all directions—but which rarely have their counterpart in nature—are needed, as indicated in Figs. 67 to 70. It will be seen that in all these there are complementary gaps and overlaps. Figs. 67 and 68, in the ultra-technical classification, would usually be regarded as representing, respectively, a normal downthrow and a reversed upthrow, with a rather high hade, while Figs. 69 and 70

would be held to represent similar classes with a relatively low hade. How little this ultra-technicalism in artificial cases means dynamically appears from an inspection of the figures, and from the fact that Figs 67 and 70 are the same, in different positions, as are also Figs. 68 and 69. This is not the double entry referred to above, but it illustrates the indeterminateness of mere geometric figures in isolation from natural settings. The geneses of these artificial faultings is quickly detected in the evidences that squares, crossed by lines, have been cut and shifted. If the natural forms for which these are usually made to stand were found set in the crust of the earth, the dynamics involved would usually be detected with satisfactory positiveness, but sometimes this is



FIGS. 69 and 70. Illustrating complementary gaps and overlaps in cases usually interpreted as normal and reversed, respectively.

extremely difficult or practically impossible. If the faulted tract is much broken, and many individual blocks enter into the composite deformation, and these are variously tilted and dislocated, and the deformative movement is itself more or less torsional, rotational or differential in some of the manifold possible forms, the complications may become very puzzling. They are rendered all the more difficult to decipher and interpret because of the double entry system by which they are recorded. Curious contradictory expressions of expansion and contraction, or what seem to be so to first appearances, are liable to appear in the complementary gaps and overlaps that present themselves in the combination of section and plan necessary to bring out the full geom-

etries. These puzzling expressions are apt to be multiplied if there is, at the same time, a differential translatory movement of the whole complex mass rather than a simple deformation in place.

The geometries of faulting may obviously be treated from other points of view, but none can be complete without a recognition of the Janus-faced aspect of the phenomena which springs from the necessity of preserving, essentially, the constancy of volume of the rock mass affected, and in this perhaps lies the chief scientific value of this mode of treatment. It must be noted, however, that this double expression is fully realized in faulting only when the whole deformation takes the form of faulting, and that this is far from being always true. This double expression is partially realized only to the degree that faulting replaces the other modes of deformation. The method carries an obvious admonition relative to the dangers of less than a three-dimensional study of the phenomena. It carries, at the same time, the signal of its own danger in its very emphasis of the equality of the complementary actions and in the liability to neglect the radical fact that one of these complementaries is an expression of the initiative agency, while the other is but the consequence of this. The soul of the problem, from the point of view of the philosophic geologist, whatever may be the immediate needs of the economic geologist—and I suspect his higher interests are the same—*lies in detecting the initial agency*. The complementary results, in their antithetical phases, are each equally the sequences of this. It is for this reason that interest centers very properly in the genetic and dynamic elements of the problem, and must continue to center there until their solution is accomplished.

In the principle of the equivalence of the complementary elements of fault-deformation, there lies a theoretical possibility of determining *the depth of the shell affected by the faulting*. Given, for example, a faulted area whose two horizontal dimensions have been increased by given amounts, and whose vertical depression is known, the depth of the zone affected is deducible by means of the formula

$$mnx = (m + a)\ (n + b)\ (x - v),$$

when $m$ and $n$ represent the original horizontal dimensions; $a$ and $b$ the additions to these respectively; $x$ the original thickness affected, and $v$ the reduction of this thickness. In practice there is an obvious difficulty in securing good expansional and depressional data for such a computation. The method is closely analogous to that we have used in determining the thickness of the shell involved in folding, by deductions from the dimensions of the folds and the elevation of the folded surface.[1] The shell involved in folding and in faulting is probably identical, at least for the major cases.

THE GENETIC AND DYNAMIC PROBLEMS OF TYPICAL FAULTING.

Were there no other than thrust-faulting and its obvious accessories, derivatives and complementary tensional faultings, the difficulties of reaching dynamic and genetic solutions would be relatively small, for the elucidation of thrust-faulting is at bottom the same as that of crust-folding, and the phenomena of folding are so declared that they point unequivocally to lateral pressure as their cause. They have thus led to genetic and dynamic theories to fit them. Whatever the strength or weakness of these theories they carry thrust-faulting as an incident of folding. These theories usually center about the postulate that the earth's volume has shrunk progressively or at intervals during the known history of the earth. In so far as we accept this we may throw the ulterior solution of thrust-faulting back upon it.

It is not improbable, however, that the greatest of all the thrust faultings is yet to be recognized generally. I refer to the possible, if not probable, shear of the earth's shell over its sub-shell, a shear that seems to be a necessary attendant of such foldings as the shell has suffered. If a shortening of the arc of the surface of some tens of miles is involved in the more important of the folded mountain ranges, it seems logically necessary to conclude that the shell on one or both sides of these ranges has sheared over the sub-shell to an amount complementary to the shortening expressed in the folds. This shear appears to have been assigned usually to a liquid or quasi-liquid movement at the

[1] Geology cited, Vol. II., pp. 125, 126.

base of " the crust," by which expression is meant some phase of the conception of a rigid exterior resting on a mobile substratum. This may be either the old view of a solidified layer of the supposed original liquid earth, resting on a still unsolidified molten zone, or some modification of it, or some substitute for it. But a study of the thicknesses of the shell involved in mountain folds seems to require that the horizon of shear should be put much nearer the surface than these views, or at least the most of them, permit.[1] The balance of evidence at present seems to locate the shear zone largely in the horizons in which *granulation* under stress, rather than *flowage,* prevails. The distinction between deformation by granulation and deformation by quasi-flowage, or by true flowage, has been clearly brought out by Adams, Van Hise, and others, and seems to rest on a secure experimental and observational, as well as theoretical, basis. If the shell shears over the sub-shell in the zone of granulation, *i. e.,* within the lower part of the zone of fracture, the phenomenon is of the nature of faulting, though it is probably a very distributive form of faulting. I should not be disposed to urge its recognition as faulting here, did I not think that this shear plane below the shell probably plays a radical role in the greater phases of the fault phenomena which we have been so long trying to explain with indifferent success. I look upon this shear-zone as the base-plane of the greater fault blocks, and as an essential factor in the development of the greater fault systems that appear at the surface. The greatest of the overthrust fault planes—such, for example, as that of Alberta and Montana brought out by McConnell and Willis, respectively—are perhaps nothing more than the outcropping edges of the fault plane at the base of the shell, which in these unusual cases is extruded. The three miles of rock above the Montana-Alberta fault plane is of the order of magnitude of the shell-thickness as deduced from the folds of mountains. Such outcropping overthrusts of the shell, in nearly or quite its full thickness, are interpreted as but incidents in the general overthrusting of the shell upon the sub-shell, which seems to be a necessary condition of mountain folding. The original

[1] Geology cited, Vol. II., pp. 125–6.

formation of this general shear plane beneath the shell is assigned to the intense lateral thrusts that are supposed to have arisen from the great shrinkage-deformations. Once established by this agency, the shear-planes may yield to lesser stresses. By virtue of this, the shear-zone is made a factor in the views of prevalent *normal* faulting to be discussed presently.

However all this may be, the general conception of thrust-faulting is intimately associated with thrust-folding and is a part of our recognized dynamical phenomena, and hence our conceptions of this class of faulting are about as well grounded as are those of folding.

The serious phase of the fault problem only presents itself when we face the observation that much the larger number of known faults are of the kind which imply a horizontal *extension* of the shell of the earth. The dynamic implications of this class are directly opposite to those of the preceding class. But we have no basal postulate for a prevalent extensional agency which is, by any means, as well accepted as the postulate of horizontal thrust; and if we had, it would remain to reconcile the one with the other and to show how they work together consistently in spite of their opposite natures. Unless, therefore, we challenge the concurrent observations of a century as to the prevalence of horizontally extensional faulting, or else question their common interpretation—and I am not at all disposed to do either, as to their main import—we must recognize in faulting a two-faced problem, for one-half of which we have current postulates which seem applicable and, in the main, adequate—in the proximate sense—but for the other half of which we have not. To find a sufficient agency for the prevalent surface tension implied by normal faulting, to show how it cooperates with the lateral thrust implied by folding and thrust-faulting, and to find a consistent place for both in a logical system of general earth-dynamics, is one of the most declared of the outstanding problems of geology. I say declared, rather than radical, advisedly, for faulting can scarcely be called a basal phenomenon; it is rather a terminal and superficial phenomenon; its problem is less a fundamental prob-

lem than an end problem. Normal faulting is apparently but a surficial expression of some process that is prevalent in the internal dynamics of the globe and is connected with the whole system of deformative dynamics, and hence is to find its solution as a part of the more basal deformative problem which, in turn, finds its solution in fundamental earth dynamics.

It was chiefly a realization of this large unsolved factor of the fault problem that led Professor Salisbury and myself, in preparing the formal statement of faulting in the first volume of our work on geology—whose limitations Dr. Ransome criticized—purposely to leave the conventionalities of faulting in their simplest current form, until they could be put on a more satisfactory basis. As these in their generic senses seemed to present the main truths generally recognized by geologists, it did not seem to us best to burden students with the intricacies of accessories, secondaries, and divergencies, nor with the inutilities of the geometries, so long as darkness hung so heavily over the meaning of the most prevalent phase, and probably the most significant phase, of the major phenomena. It seemed better simply to present the current ideas of the most familiar faultings in the conventional way and to reserve as much as practicable of the space that could be given to faulting for such contributions as we could make to the unsolved phases of the problem.[1] In the scheme of the treatise, the basis for a treatment on our own preferred lines—at least so far as they lay in the system of dynamics based on the planetesimal hypothesis—was not then laid. At the close of the discussion on earth-genesis in the second volume, pp. 122–132, some of the necessary groundwork for this was introduced, but necessarily with brevity. Some further development was given in the historical chapters, Vol. II., pp. 233–236, and Vol. III., pp. 12–23, 519–578. Pending a more mature consideration of these, and at least some careful testing

[1] These contributions may be found in Chamberlin and Salisbury's "Geology," Vol. II., pp. 131–132, 233–236, Vol. III., pp. 12–23, 519–528. The more fundamental considerations from which these arose may be found in Vol. I., Chapters IX. and X., and Vol. II., Chapters I. and II.

in practice, it was obviously premature, as I still feel it to be, to attempt the revision of the classification and nomenclature of faults, or to lay down rules for their interpretation. We could only cherish the hope that at some early day it would be possible to revise the treatment of faults on a broader and better basis.

*To be continued.*

T. C. CHAMBERLIN.

## *HOW SHOULD FAULTS BE NAMED AND CLASSIFIED?*

*Sir:*—I have read with interest the contributions to the discussion of faults which have appeared since my short letter on the subject. A paper of Mr. Tolman, in particular, has appealed to me as a geometrically sound discussion of the different natural fault functions. Mr. Tolman proposes to define and name a number of functions which I did not define in my earlier papers upon the subject, although I noted the existence of such. I did not, however, consider that at the time the state of geological work warranted a more complete set of definitions than I then proposed. I am still in some doubt upon this point; but it is certain that we are nearer the time when a complete classification will be necessary than we were ten years ago. Mr. Tolman also proposes certain changes in my terms, partly to make the terms easier to memorize and partly for the sake of conformity to a uniform scheme.

In general, without having weighed with sufficient care the necessity of defining and including in the classification some of the functions which Mr. Tolman enumerates, I believe that his propositions are in the line of improving matters of nomenclature. His proposition to call all measurements upon the fault-plane displacements, those normal to the fault-plane and a faulted bed separations, those taken in in vertical section throws, and those shown on a horizontal section heaves, is one which will help in holding the different functions in mind; and the same is true of the orderly employment of the terms "total," "perpendicular," "parallel" and "horizontal." It might seem at first

sight as if the classification has been elaborated upon by Mr. Tolman too extensively; but as the necessity for nearly every one of the measurements has been insisted upon by one writer or another, I am inclined to believe that with one or two possible exceptions the list is a very useful one. The two terms about which I am most in doubt in regard to the necessity of their being included are "vertical separation" and "horizontal separation."

J. E. SPURR.

NEW YORK, September 14, 1907.

# REVIEWS

**Clays, their Occurrence, Properties and Uses, with Especial Reference to Those of the United States.** By HEINRICH RIES, Ph.D., Professor of Economic Geology, Cornell University. Pp. xvi + 490. 44 plates and 65 figures. John Wiley & Sons, New York, 1906.

The book on clays which Dr. Heinrich Ries has recently issued is a work in which are compiled data from numerous reports and widely scattered papers by the author and others, supplemented by such new research and experimental work as to bring the publication up to date. It is written by one of the foremost clay geologists in the country, in a style not often found in the writings of college professors; that is, the text-book feature is totally absent.

As the title of the book indicates, the principal sections deal with the occurrence, properties and uses of clays. It can readily be understood, therefore, that the work is not a publication, like Bourry's "Treatise on Ceramic Industries," which deals essentially with machinery and manufacturing processes, but is intended to give information to any one who is interested in clay and its industry. The collection in one volume of up-to-date information relating to the occurrence of clays in the different states obviates the trouble of hunting through many papers and State reports, some of which are either difficult to obtain, or out of print.

In Chapter I., on the Origin of Clays, the author handles the subject in an excellent manner and shows that a satisfactory definition of clay is difficult. Not all clays, as has been shown, are derived from feldspar, a fact overlooked by many writers. Kaolinization by pneumatolysis is a mode of origin emphasized by some writers, but the author indicates that kaolinization is usu-

ally a weathering process. The distinction between kaolin and kaolinite, which is often confused, is a well-taken point. In the classification of clays, we find six writers quoted, with as many classifications. The author gives also his own classification, which is consistent and simple. The changes which have occurred during the deposition of clays are described and illustrated, and give a good idea of the different secondary phenomena which take place.

Chapter II., on the Chemical Properties of Clays, is a very interesting and important one. The partial detection with the naked eye of the mineralogical character and structure of clays, as a guide to their value, is well advised, for the pyro-chemical behavior of clays is largely influenced by the ingredients present. Furthermore the fact, here presented, that clay may contain a great variety of minerals disproves the common statement that clay "is hydrated silicate of alumina." The commonly expressed opinion that kaolinite is the basis of all clays is vigorously denounced by the author and his explanations are of great value in solving this very important question of the actual composition of clay. The citations from various writers show what a vast amount of research work is done in this line and prove that kaolinite is not the only hydrated silicate of alumina present. Halloysite, pholerite, nacrite, allophane and other minerals have been found associated with the kaolinite. The minerals which make up clay are treated in the order of their importance and the effects of silica, iron, lime, magnesia, alkalies, titanium, water, carbonaceous matter and soluble salts are discussed.

The author states Seger's and Orton's views upon the coloring action of iron oxide, and shows that they are not in strict accord. He explains in detail the action of lime and alumina on iron and the results produced in bleaching the red color in certain clays. In regard to the effect of magnesia and titanium, the latest published contributions on this subject are cited.

A short statement upon chemical and rational analyses and their interpretation ends the chapter on chemical properties.

In Chapter III., the physical properties are treated in a general way and plasticity is given due prominence. There seem to be

so many definitions of plasticity that the author does not feel justified in advancing another. He agrees with Zschokke in believing that the usual conception of plasticity is too narrow.

The various methods for the measurement of plasticity are described, the author giving preference to that of Zschokke. Method of separation and of determining tensile strength test are generally described. Shrinkage, porosity, specific gravity and fusibility are also thoroughly treated. The different stages of vitrification are mentioned and the effect of chemical composition on fusibility discussed. After quoting Richter's experiments, Dr. Ries presents a diagram showing Seger's experiments with a mixture of kaolin and silica, in which we find that 10 per cent. kaolin and 90 per cent. silica form the most easily fusible mixture. In discussing the fusibility factor the author quotes the formulas of Bischof, Seger and Wheeler without expressing preference and gives it as his opinion that a statement of actual temperature of cones of fusion is more valuable than a factor deduced from a formula based on a chemical analysis. The formulas quoted are as originally published, with the exception of the Seger formula, which is simplified. Measurement of fusibility is next taken up and cones, pyrometers, and other methods are described. In describing the changes which take place in burning we find many valuable explanations. Remarks on color, slaking, permeability and absorption conclude the chapter.

Chapter IV. is a brief account of the kinds of clay employed for different purposes, beginning with the highest grades. It includes kaolin, ball clay, fire clay, stoneware clay, terra cotta clay, sewerpipe clay, brick clay, fireproofing clay, slip clay, gumbo clay, paper clay, mineral paint clay and others. A chemical analysis, physical tests and distribution are given for each clay. Under kaolin we find a table of analyses of all principal kaolins, domestic and foreign. Fire clays are treated in full. In explaining the effect of silica on fire clay, the author refers again to the Seger experiments and describes them in detail. Experiments of his own to verify Seger's results are also described. In plotting his curves, the author replots Seger's original curve in order to show the slight difference which he obtains in the same experi-

ments. In the original Seger experiments the abscissæ were in equivalent composition, while Ries uses percentage composition. This makes the form of the curve slightly different, but does not affect the results. As Seger used Zettlitz kaolin, and calls same alumina (Thonerde), Dr. Ries is quite right to use a white-burning clay and to plot both curves in percentage composition of kaolin and silica. The results are similar to those of Seger, but somewhat lower. For stoneware clays there is also given a table of analyses which is of great value and on brick clays is an important note on flashing. Slip clays are also treated thoroughly.

The second part of this chapter deals with methods of mining and manufacturing and gives in a concise form the different processes and machinery used in the making of the different classes of clayware. The clear explanations give a good idea of the different methods used without burdening the reader with detailed descriptions of mechanical processes.

Chapters V., VI. and VII. treat of the distribution of clays in the United States. It is a very useful summary for general reference and a compilation which fills a long-felt want. Under each state is a bibliography.

Chapter VIII. describes fullers earth and gives a very interesting description of this material.

The book is printed in good clear type on good paper. It has a table of contents, a list of illustrations, a list of abbreviations and a general index.

The whole publication is a valuable addition to English ceramic literature, largely because it is such a complete and concise compilation of nearly everything of value that has been published relating to the origin and properties of clays in general and to their distribution in the United States in particular. It is the best reference book on American clays published to date.

S. GEIJSBEEK.

**Die Erzlagerstätten. Unter Zugrundelegung der von Alfred Wilhelm Stelzner hintenlassenen Vorlesungsmanuskripte und Aufzeichnungen bearbeitet.** Von Dr. ALFRED BERGEAT. II. Hälfte. 1. Abtheilung. Mit 65 Abbildungen und 2 Tafeln. 2. Abtheilung. Mit 154 Abbildungen und 4 Tafeln. Leipzig, Verlag von Arthur Felix, 1905 und 1906. Pp.

The first part of the important Stelzner-Bergeat handbook of ore deposits, published in 1904, was reviewed in ECONOMIC GEOLOGY, Vol. I., No. 1, pp. 85–87. The second part has recently been issued and is bound in two divisions, the whole work thus consisting of three volumes with 1330 consecutively numbered pages. At the end of the last volume is an excellent index by localities and by authors.

The first volume began with a very brief systematic discussion, following which the ore deposits of igneous and sedimentary origin were described. The two later volumes are devoted chiefly to the epigenetic ores—those filling fissures and other cavities, and those of metasomatic origin. A comparatively brief space is given to the metathetic, eluvial, and alluvial deposits.

It is perhaps best to begin with a resumé of the scheme of classification adopted in this book. The ore deposits are divided into two principal groups, protogenetic and deuterogenetic, which practically is equivalent to primary and secondary. The latter include the ordinary alluvial deposits or placers derived from a primary deposit by transportation and concentration. They also cover the metathetic deposits by which term is understood concentrations which take place *within* a given rock mass; in other words, a deposit caused by chemical and mechanical means. This conception is evidently restricted by the author to processes carried on by the vadose circulation relatively close to the surface. As the author states, all products of change and enrichment in the upper part of ore deposits really also belong to this class of deposits. Specifically, the residual iron ores, the bauxites, the laterites, and saprolites belong in this class.

The primary deposits are divided into syngenetic and epi-

genetic. The former include the igneous and the sedimentary groups, according to whether the ore minerals were originally consolidated from a molten magma or deposited together with sediments in seas or lakes. The epigenetic deposits form a very large class and are divided into those:

1. Filling fissures.
2. Filling caverns.
3. Metasomatic deposits.

The important group of fissure veins is further subdivided as follows:

I. Hydatogenetic veins.
   A. Primary filling of oxides.
      1. Hematite and limonite veins.
      2. Nickel hydrosilicate veins.
   B. Primary filling principally of sulphides, arsenides, and antimonides.
      3. Gold veins.
      4. Silver veins.
      5. Lead and zinc veins.
      6. Copper veins.
      7. Nickel-cobalt veins.
      8. Bismuth veins.
      9. Antimonial veins.
      10. Arsenical veins.
      11. Mercurial veins.

II. Pneumatolytic-hydatogenetic veins.
      12. Tin veins.
      13. Tourmaline-copper veins.
      14. Tourmaline-gold veins.
      15. Ilmenite veins.

III. Injected veins.
      16. Injected pyritic ores, galena, and zincblende.

The metasomatic deposits and the fillings of caverns are treated together without further subdivision.

It is scarcely necessary to point out the inconsistencies of this scheme of subdivision of the epigenetic deposits. It should be

said, however, that little attention is given to this classification which seems merely to serve as a rough filing case for the wealth of detail contained in the book.

In the review of the first volume the criticism was made that the sedimentary deposits included many extremely doubtful cases and several occurrences in which the ores are assuredly not of such origin. Among these were the Scandinavian iron ores, even including the Gellivare and the Kirunavaara types; the bankets of the Transvaal, the gold ores of the Homestake mine of South Dakota, and, finally, the pyritic deposits of Agordo, Rammelsberg, Mount Lyell, and Norway.

Volume II. opens with a general discussion of fissure veins (pp. 470–571). In many respects this chapter is unsatisfactory, especially in the treatment of faults. The statement of the origin of fissures is also open to criticism; no mention is made, for instance, of the effects of compressive stress in producing conjugated fracture systems. The treatment of the "Ganggesteine," or metasomatically altered rocks accompanying fissure veins is very incomplete and evidently represents the standpoint of about fifteen years ago. On the other hand, there is an excellent chapter on secondary changes (pp. 541–566) in veins. To some extent the omissions in the general treatment of veins are filled in the third volume, which contains a chapter (pp. 987–1006) on ore shoots, and influence of country rock. At the close of the description on the epigenetic deposits, a section follows discussing their origin (pp. 1188–1240). The theories of descension, lateral secretion and ascension, are fully treated and Stelzner's elaborate arguments against lateral secretion find an important place in this chapter. The conclusion is reached (page 1205) that "there is great probability that, aside from an extremely small number of assuredly laterally secreted deposits, all epigenetic deposits have received their metal contents from great depths." And, on page. 1207, "most of the epigenetic deposits are derived from deep-seated magmas while the latter were in the process of crystallization. The authors believe that these magmas were generally granitic and that the ore deposits may be, broadly speaking, considered as a differentiation product of

these magmas. The acidic magmas may not contain more volatile products than those of greater basicity, but they probably expel them with greater energy during crystallization. These granitic magmas doubtless contain dissolved a later separated residual liquor of gases and metals. Professor Bergeat believes that certain deposits, like those of Bodenmais, Fahlun and Atvidaberg, which unite certain features of contact deposits with those of eruptive deposits, may be due to an injection of this residual metallic solution into the surrounding rocks." (See above in subdivision of fissure veins, p. 608.) It is noted, however, that Stelzner considered these deposits as sedimentary.

In the following chapter epigenetic deposits are considered in their connection with thermal springs, and much space is devoted to the composition of ascending waters. In general the conclusion is reached that the epigenetic deposits are caused by thermal springs, but concerning the magmatic origin of the water no definite conclusion is reached.

The fissure veins are described in the greatest detail, according to the classification given above. The epigenetic deposits are treated together with the "filled caverns," although the importance of the latter seems rather slight; this association is undoubtedly a survival of the old views of Stelzner's time when nearly all of the deposits, which now are considered as of metasomatic origin, were believed to have originated by filling of limestone caves. The chapter is divided into the metasomatic deposits proper, under which heading are described the lead-zinc deposits of Silesia, Bleiberg, Raibl, Santander, Laurium, Missouri, Wisconsin, Leadville, Aspen, Park City, Bingham, and Tintic. That genetically very different things are here treated together is apparent and it is evident that Professor Bergeat realizes this in part, for he speaks of the close relation of the latter five districts to intrusive rocks. For the Mississippi Valley deposits a genesis by ascending solutions is held probable.

The second division comprises the metasomatic contact deposits under which the districts of Schwartzenberg, Berggieshübel, Banat, Elba, Christiana, Sala, Bisbee, Clifton, Vancouver and

Chillagoe find mention. The metals are believed to have been deposited by emanations from granitic magmas near the contact.

In reading this book the disappointment engendered by certain defects pointed out above gradually gives away to a feeling of genuine admiration for the complete, lucid, careful, and impartial manner in which the subject matter is presented. In this respect it has surely no equal among the handbooks published up to the present time. The fissure veins show an especially masterly treatment, but no matter to which subject one may turn, he will find the same clear and perfect presentation, together with a truly wonderful command of the literature in whatever language it may be published. As a record of the geological study of ore deposits, it can be most highly recommended.

W. LINDGREN.

**Geology of the Marysville Mining District, Montana.** By JOSEPH BARRELL. A study of igneous intrusion and contact metamorphism. U. S. Geological Survey, Professional Paper No. 57. Washington, 1907. Pp. 178, 15 pls., 9 figs.

The Marysville district, situated 15 miles north of Helena, has for many years been the scene of mining activity, the two most important mines being the Drumlummon and the Gloucester, both of the general types of quartzose gold-silver veins. Of late the activity has abated on account of the closing of these two principal mines, but the vicinity still has latent possibilities. Professor Barrell's paper describes the geology of 44 square miles surrounding Marysville comprised in a special map on the scale of about two inches to one mile and with 50-foot contour intervals. It pays detailed attention to the problems of contact metamorphism and intrusion, but refers only incidentally to some of the mines, and in this respect will probably be somewhat of a disappointment to the mining man who may be interested in the locality. The deposits of the Drumlummon mine have been elsewhere briefly described by Mr. W. H. Weed,[1] under whose direction this field work was done, but it is not clearly explained why

[1] U. S. Geol. Surv. Bulletin No. 213. Contributions to Economic Geology, 1903, p. 89.

a chapter on the ore deposits could not have been added to Professor Barrell's paper.

The geological map is contained in a pocket and there is also a sheet of cross-sections which excellently portray the structure of the region.[1] The field work was done in 1901.

The continental divide crosses the district with a maximum elevation of 7,329 feet. The region exhibits the character of mature mountainous topography with faulty steep slopes, rounded hill crests and gulches with deeply incised amphitheaters. A summary of the geology is given on the first twenty-six pages, but it is noted with some regret that no resumé is available of the important detailed chapters on structure, contact metamorphism and intrusion.

The Belt group of sediments, referred to the Algonkian, covers much of the mountainous region of the area. It is non-fossiliferous, is comparatively little altered, has a total thickness of about 6,000 or 7,000 feet and in general lies flat, or dips at gentle angles. Beginning with the oldest division the group contains the following formations: Greyson and Spokane shales and sandstones, Empire calcareous shales, Helena impure limestone and Marsh shale. The sediments contain no fossils and their continuity is broken by a number of faults.

Near Marysville, in the highest part of the quadrangle, these formations are invaded by a batholith of granitic rock forming a pear-shaped area somewhat over two square miles in extent. The rock is said to be a quartz diorite, but the field name ordinarily given to it is granite. As a matter of fact, the term quartz diorite fits it poorly; it is an intermediate rock like so many batholiths of this type and corresponds exactly to a granodiorite. Subordinate intrusives occurring in the district are microdiorite, gabbro, various feldspar porphyries, aplites and pegmatites.

The aplites, pegmatites and some of the feldspar porphyries are regarded as later differentiations of the granitic rock. They

[1] Some of the underground contact lines in this district are known by mining developments, while others are entirely hypothetical. It would have been better to have the definitely known facts of this kind separated in some way on the sections from the inferred lines.

cut the latter but are, on the other hand, older than the mineral veins. No direct connection is discernible between pegmatites and the fissure veins.

Aided by the extensive mine developments, the author traces in detail the underground contacts of the granite and shows their extremely irregular course. The general conclusion is that the granitic mass rapidly broadens downward in irregular pyramidal form, and it is held probable that it unites with the underground extension of the much larger Boulder batholith.

A general doming and arching of the sediments occurred in late Cretaceous or earliest Tertiary times, lifting the surface several thousand feet above the present level. Marginal faulting of the dome followed and after this came the great intrusion of the granite. The latter did not reach the surface but has been exposed by subsequent deep erosion.

According to the author, the veins which are mostly found near the contacts of the granite are due to the filling of peripheral contraction fissures. These served as channels for the escape of mineralized heated waters in part at least of magmatic origin which deposited in them auriferous quartz, fluorite and calcite, together with silver, copper and iron sulphides. Weed states that the Drumlummon vein has been developed for 3,000 feet horizontally and to a depth of 1,600 feet, but no ore was found below the 1,000 foot level. The richest ores occur as bonanzas within 200 feet of the surface and then rapidly decrease in value as depth is gained. Sulphides and sulphantimonites of silver, with native gold, are the valuable minerals, the gold aggregating 60 per cent. of the total value.

Near the veins the feldspars and the biotite of the granite are sericitized and infiltration of quartz and fluorite has taken place. In some of the hornstones or contact metamorphosed sediments the diopside next to the seams of quartz and fluorite has been altered to fibers of hornblende. This observation recalls the metasomatic action in certain veins cutting the altered sediments at Morenci.

Chapter IV., pp. 116–150, one of the most important sections of the report, describes the contact actions. The Marysville

batholith is surrounded by an aureole of contact metamorphic sediments which is from one half to over one mile wide, and in which shales have been converted to hornfels and the limestones recrystallized to marble or various silicates. The locality is not one of the very best for the study of this subject, for (1) the contact metamorphic ore deposits are lacking except for local development of pyrite; (2) the pure limestones are few, and (3) it is difficult or impossible to trace individual beds from the unaltered into the altered zone. Nevertheless, the results achieved are important and the whole chapter indicates that the author's view has broadened very decidedly since the publication of his first papers on the same subject at the Elkhorn mine, Montana.

Two distinct classes of contact action are noted: (1) Contact metamorphism, consisting merely in recrystallization of the rocks such as pure limestone to crystalline limestone. In impure limestones water and carbon-dioxide are expelled and the silica combines with a proportional amount of bases set free.

This latter case is really a metasomatic action, but the author separates it from (2) contact metasomatism, in which magmatic emanations add some of their constituents to the altered sediments. "Silica and iron in water solution seem most important, but sulphur and other elements are also involved." Pure carbonate rocks are most easily affected. Contact metasomatism may be pneumatolytic or hydrothermal, corresponding to temperatures above and below the critical point. The former results typically in the formation of heavy anhydrous minerals within the contact zone, while hydrothermal action takes place at greater distances from the still hot magma and results in vein filling and metasomatic alteration of the wall rocks, both grading one into the other.. In hydrothermal processes meteoric water doubtless mingles with that of magmatic origin. At Marysville the affected rocks were in the zone of fracture, perhaps only a few thousand feet below the surface and a minute and extensive fracturing facilitated the permeability of the sediment for the emanations.

In the metamorphic zone, more than one thousand feet from the batholith, the composition of the strata point to little or no

accession of material from the magma during metamorphism. Within this distance, magmatic siliceous emanations, generally combined with the lime and other bases, resulting in lime-silicate hornfels with the accompanying elimination of carbon dioxide. In places, however, marbles may be found relatively near the granite.

In one typical case, some distance from the contact, the metamorphic rock is a banded hornstone (the author's term for the more commonly used "hornfels") of brown mica, tremolite, quartz, feldspar, calcite and zoisite. This is traversed by cracks filled with epidote, along which the brown mica has been destroyed and bleached. It is held that the hornfels was produced without addition of material by a first wave of metamorphism, the agency being water gas. Fracturing and infiltration of foreign material from the granitic magma followed.

Nearer to the contact similar hornstones are more abundantly infiltrated with foreign material. The planes of infiltration are here more commonly parallel to the bedding. The minerals developed on these planes chiefly follow the calcite bands, are later than the elements of the hornstone and consist mainly of diopside and quartz. It is held that in this process the magma has furnished much of the silica of the diopside.

Very near to the contact streaks of hornblende have developed at the expense of the biotite of the hornfels. Epidotization along fractures and slight accession of apatite and tourmaline along the contact closed the series of processes. Pyrite was noted from a few places associated with garnet and pyroxene.

A certain sequence of magmatic after-effects is thus recognized. The general metamorphism is followed by siliceous infiltration nearer to the magma and the formation of garnet and pyrite very close to the contact. It is suggested that in the magmatic emanations the earliest eliminated products immediately after the intrusion may have been the freest from elements producing metasomatism. The reviewer believes that in sedimentary complexes which have received more liberal additions from the magma than would appear to have been the case at Marysville, the author would have found it extremely difficult

to separate metamorphism from metasomatism. There can be no doubt that the general metamorphism is followed by special infiltration, but that the first attack should be distinctly separate from a second and that the latter only resulted in addition from the magma the reviewer finds difficulty in believing.

In a previous paper Professor Barrell has called attention to the shrinkage of volume which theoretically should result from metamorphism without additive metasomatism, and asserted that he found evidence of this in the study of the Elkhorn district. At Marysville, however, the field evidence of diminution of volume is practically nil and the author's explanation that in spite of this a considerable shrinkage has occurred is scarcely convincing.

The last chapter discusses the methods of igneous intrusions in this region, and is of general interest as applicable to an enormous number of intrusive bodies in the Western states. The invasion of the sediments by the batholith was not accompanied by marginal assimilation; the contacts are in all cases sharp and distinct; no evidence points to melting or extensive injection of the sedimentary rocks. Faults do not in any measure account for the general form of the intrusion. This precludes that the intrusive mass has the character of the bysmaliths of Iddings. Lateral thrust has not been a factor of importance and no peripheral schistosity has developed in the surrounding rocks. The laccolithic hypothesis is then tested and rejected as far as applicability to the present case is concerned. The cover of sedimentary rocks and possibly andesite was comparatively thin for the erosion of a few thousand feet of vertical measure was sufficient to expose the granite. No evidence of a bottom was found to match the original cover, although a vertical depth of 4,000 feet of granite is exposed by erosion.

By the process of elimination the result is arrived at that the intrusion took place, according to Daly's theory, by a passive invasion and stoping by the subsidence of large roof blocks. The magma is conceived to have been fluid or semi-fluid at the time of the intrusion and the absence of an abundance of such blocks in the granite is accounted for by their sinking in the magma.

At the contacts, however, evidence is found suggestive of the rifting away and subsidence of large individual rock masses. The maintenance of the cover of sediments over the batholith is explained by the supposition that the bottom was slowly pushed down by the magma as the magma advanced under hydrostatic pressure and that finally the magma was chilled and became viscous near the surface. The difficulty of the subject is very great and even in the finally adopted explanation many doubtful points remain.

The highly commendable characteristics of this paper are clearness and a logical presentation of observations and theories. It records a painstaking and successful effort to elucidate the problems connected with intrusions, and forges another link in the strong chain of evidence connecting igneous rocks and ore deposits.

W. LINDGREN.

**Zinc and Lead Deposits of the Upper Mississippi Valley.**[1] By H. FOSTER BAIN. U. S. Geological Survey, Bulletin No. 294. 1906. Pp. 156. 16 plates, including map.

There has been much written on the lead and zinc district of the "Upper Mississippi" valley, each succeeding report containing an increasing volume of abstracts from the preceding ones. Bain's report is no exception to this rule, but the manner in which the increasing volume of literature on the district has been handled in this bulletin is worthy of special commendation.

The historical sketch is well balanced and, with the exception of one date, is accurate, in so far as I am able to judge. The date referred to is on page 6, on which it is recorded that the

[1] The reviewer has always maintained that, in reviewing the work of another, one should endeavor, as far as possible, to distinguish clearly between that portion of the review which is an abstract and that portion which contains his own comments. He should also indicate clearly that which is merely a repetition of what has been published in earlier reports and that which is new to the present work. This is not an easy task and in its accomplishment one is liable to make mistakes which will subject him to criticism. It is sometimes difficult also, to interpret clearly the idea which the author wishes to convey, inasmuch as he frequently fortifies his position with so many conditional circumstances.

Wisconsin Geological and Natural History Survey was organized in 1899. It should be 1897.

The discussion of the topography of the region contains nothing essentially new. Bain discusses in a few pages the mounds and escarpments, the upland and valley tracts, and the ages of the two well-recognized peneplains.

The chapter on stratigraphy is a compilation of the results of the work of former geologists, mainly the coöperative work of the Wisconsin and United States Geological Surveys of recent years. In this Dr. E. O. Ulrich's proposed classification is followed very closely. It would have been convenient, in the compilation of the general section, to have added in parentheses the formational names used by the earlier geologists.

Dr. Bain discusses briefly the possibilities of unconformities between the St. Peter and Platteville, between the Platteville and Galena and between the Galena and Maquoketa, without reaching any definite conclusion in any case. He is, however, inclined to believe that the evidence is insufficient. For example, he says, "The relations of the Maquoketa to the Galena, while probably those of unconformity, are not altogether clear."

In this connection it might be recorded that drilling shows that between the Galena and Platteville, particularly in Illinois, there is a thin but rather persistent layer containing grains of sand. This, of course, has only a slight bearing on the question of unconformity, although it is important from the standpoint of the prospector, and should have been noted.

Bain devotes considerable space to a discussion of the oil rock, reviewing the laboratory investigations of Grout, White, Rollin Chamberlin and J. W. Murphy, all of which show the highly bituminous nature of the material and its origin from "unicellular gelosic algæ" (White).

Mention is made of fragments of "a slightly harder rock" in a matrix of softer material in the oil rock. Bain states his belief that these fragments have been bent and broken as a result of stresses. In this connection it might be said that these fragments are believed by some to be simply lenses, unbroken by any stress. A short time ago one of the operators in the district

cited to me an instance of a boulder 5 feet in diameter on opposite sides of which were found small lenses, which from their position, shape, and composition could not have been derived from the large boulder.

In a discussion of the origin of the dolomite, which occurs with the limestone beds of the Galena formation, Bain inclines to the belief that "the process of alteration from limestone to dolomite followed their original deposition."

The pages on geologic structure are devoted chiefly to a discussion of the so-called basin structures of which the following four types are recognized: "(1) Broad, shallow basins; (2) flat monoclines; (3) sharply asymmetric anticlines; (4) canoe-shaped basins." Illustrations of the basins are introduced, but the data upon which the contours are based are not given. The maps of the important areas, it is thought, would have been more forceful had the data upon which they were constructed been added. These basins are thought to be, in the main, a result of consolidation of the oil rock, although the author cautiously includes original sedimentation and deformation as important and in some instances predominant factors in their formation. In reading the report one is at somewhat of a loss to know upon which one the greatest emphasis is placed, although I am led to believe that consolidation of the oil rock has assumed in the author's mind a place of first importance.

Faults, of any appreciable magnitude, have not been recognized in this district.

Vertical and inclined joints are well developed. Bain believes the vertical joints to be due to the deformation which produced faulting, while he refers the inclined joints to "the same agency that caused the sag." They are "believed to be an expression of the settling of the rocks due to decrease in bulk of the oil rock."

Bain's discussion of fractures is confined chiefly to the Galena formation, but somewhat extended observations over the area show that the pitching fractures occur not only in the Galena formation, but also in the Platteville limestone and the St. Peter sandstone. These evidently cannot be attributed to the decrease

in bulk of the oil rock and for this reason I am inclined to believe that Bain's hypothesis to account for these fractures is not as sound as the mechanical deformation explanation offered by Professor T. C. Chamberlin in an earlier report on the district.

There is still another fact that renders Bain's explanation open to question. There are pitching fractures in the *upper* part of the Galena formation which in the early days carried bodies of lead ore sufficiently rich to be mined. These must be explained as well as the more important ore-bearing fractures in the lower part of the formation.

In the discussion of the manner of occurrence of the ores very little has been added to what has already been published in the earlier reports. Bain distinguishes four general forms of ore bodies, viz.: "(1) Crevices and openings; (2) honeycomb or sprangle runs; (3) pitches and flats; (4) disseminated ores."

Reference is made to the preponderance of galena in the upper beds and of zinc blende below, and in this connection Bain says: "There are some good reasons for thinking that there may have been originally a greater abundance of galena in the upper beds."

I agree perfectly with Bain in this belief. The evidence given by him to support this contention is in part the same as I have used to maintain a similar contention in the case of the ores of the Joplin district.

Bain agrees with Chamberlin in believing that the original source of the metals was the igneous rocks of the Lake Superior region. He also agrees with Chamberlin in believing that the ore bodies have resulted from a concentration of metallic salts originally disseminated through local areas of the Galena limestone, by the action of descending surface waters. He believes that the present ore bodies were formed in late Tertiary or post-Tertiary time.

In his discussion of the mode of occurrence of the ores, Bain refers to metallic sulphides as replacing shale. This is the first time that my attention has been called to a metasomatic replacement of shale by metallic sulphides in this region and I regret that Bain does not mention concrete instances in proof of this.

Bain's discussion of the flats and pitches in three dimensions

is interesting and important. Heretofore this has not been sufficiently emphasized.

With the exception of the disseminated ore, which is a metasomatic replacement of the rock, all the sulphide minerals, according to Bain, occur in openings which have been formed by solution.

It would have been interesting to have known when these openings formed with respect to the deposition of the ores. During a period when solution was active widening joint planes and opening up cavities, it is doubtful if the metallic sulphides could have been deposited in the incrusted forms now observed. Evidently an important step in the history of the ore deposition has been omitted.

It is interesting to note that artesian conditions exist in this region, but it is surprising that Bain has omitted any mention of the quantity of water now being pumped from the mines. From this he might have given an estimate of the quantity of artesian water now passing into and through the ore-bearing horizon. He says, however, "the writer would hold that the wide-reaching artesian circulation probably had little, if any, effect in producing the ore bodies of the area." This Bain frankly confesses is "a reversal of an opinion held in 1902."

Bain says that in the main the ore bodies are confined to the areas in which the oil rock is thickest. The converse is not true and there are exceptions to the rule, as shown by numerous drill holes.

Fifty pages of the Bulletin are devoted to a "Description of Mines and Districts." As a rule, the descriptions of mines are accurate, but in some instances the comments are infelicitous, as in the case of the "Peru or Black Jack" mine, which is working a fine ore body from four shafts. Bain says of this mine: "About 1903 a new mill was erected and the mine pumped out and examined preparatory to resuming work, but apparently the ore reserves were unsatisfactory, as the plant was closed down."

Perhaps the most interesting part of the bulletin is the discussion of the genesis of the ores, which accounts for the geographic distribution, the geologic position and the mode of occurrence.

The original source of the metals is supposed to have been the crystalline rocks of the Lake Superior region.

In brief, the author argues against a deep-seated origin, holding that the "immediate formation of the deposits has been by descending waters." His objections to a deep-seated origin are the absence of "the usual characteristics of the true fissure veins of the west, slickenside and gouge being almost entirely absent," the horizontal rather than vertical direction of the ore shoots; the strikingly different association of ore minerals and gangue; the absence of faulting; the presence of stalactites; the segregation of the ore in broad, flat sheets above impervious beds; the absence of ore in the underlying lower Platteville dolomite; and the presence of great aquifers through which heated solutions could hardly rise without diffusion.

Bain believes that the lead and zinc minerals were transported from the crystalline rocks of the Lake Superior region mainly into the Galena and upper Platteville formations. He further argues that the salts of lead and zinc were carried by rivers to a portion of the Ordovician sea especially favorable for precipitation, being precipitated by hydrocarbons and hydrogen sulphide, derived from decaying masses of a peculiar type of algæ, which accumulated within certain shallow basins on the sea floor. He believes that the buried masses of algæ, through the giving off of volatile hydrocarbons and hydrogen sulphide, effected a precipitation of zinc and lead salts throughout a thickness of 250 feet of strata. The only reason given for this belief is that galena actually occurs throughout these beds. He also suggests that as the sediments above the algæ remains became thicker, the amount of hydrocarbons reaching the surface would gradually diminish until there was only sufficient to precipitate the relatively insoluble sulphide of lead and "not enough to affect the more soluble sulphides of iron and zinc." This suggestion is new and certainly unique. Its weakness lies in estimating the thickness of strata through which the hydrocarbons might be effective from the thickness of the beds through which the ores now occur. Although this may be a reason for the occurrence of the galena in the uppermost horizon, I believe that the present distribution

can be better accounted for by a process of concentration through downward circulation. He says further: "As the algæ matter became compressed the beds above broke and settled, leaving open spaces of peculiar form for the ultimate reception of the ore bodies. The beds were slightly deformed, whereby the basins were accentuated and deep joint cracks were developed. The area was subjected to peneplanation and later to gorge cutting, whereby the overlying shale was cut away and a vigorous underground circulation was brought about. This circulation resulted in a concentration of the disseminated material and with the fall of ground-water level the ores were successively reconcentrated until the present type was produced."

Bain says: "There are four well-defined types of ores, described as (1) galena ores, (2) zinc carbonate ores, (3) zinc sulphide ores, (4) iron sulphide or sulphur ores. They occur commonly in a corresponding vertical order, the galena ores being at the top. To a large extent this is believed to be a result of alteration and reconcentration of the first-formed ore bodies, in which it is thought that there was less separation of the sulphides." Bain says further on, "There are reasons for thinking that this vertical order may, in places, have been original."

In another place, in commenting upon the possibility of an early concentration through the action of wide-reaching artesian circulation, Bain says: "It is possible that further advances in knowledge of the chemistry of the process may minimize the difficulties in the way of applying it to the mines of Wisconsin and that, in the end, the broader circulation may prove to have had a greater influence than is now thought possible."

There is very little said in this bulletin relative to "first" and "second" concentrations, from which one would infer that Bain has found very little evidence of these concentrations as defined in his former publications. There is very little reference made to the possible result of diffusion in effecting a distribution of the metallic salts brought in by the ground-water circulation.

One of the most notable things about Bain's theory of the origin of the ores of this district is the reversal of the opinion which he held several years ago as published in the report on the

"Lead and Zinc Deposits of the Ozark Region," and the fact that he has ignored the facts which lead him to an opposite conclusion in a discussion of the origin of the ores of the Joplin district. For example, the absence of faulting in the Joplin district does not interfere with his theory of a deep-seated origin for the ores of the Joplin district, while it is used as argument against such a theory in the Upper Mississippi Valley district. In the Joplin district the amount of water constantly pumped from the mines is used as an argument for a deep-seated origin. In the Wisconsin field the amount of water pumped from the mines (this information is a result of my own investigations) is greater and more constant in volume than in the Joplin field, yet it is not considered in Bain's discussion of the theory of the origin of the ores. In both districts the ore bodies have none of the characteristics of the vein deposits of the western states. The vertical distribution of the ores is essentially the same in the two districts, being accounted for by Bain in one case as the result of an upward circulation modified by a secondary downward concentration, and in the other case as the result of a simple downward circulation. In both districts analyses have shown the limestone or dolomite, in which the ore bodies occur, to contain sufficient finely disseminated lead and zinc to account for the ore bodies, yet in one case the origin is deep-seated and in the other surficial.

In general, I am in accord with the theory of the origin of the ores of the upper Mississippi Valley as expressed by a downward circulation. Bain's report, however, is in no sense positive and one is left somewhat in doubt as to just what he believes to have been the nature of the circulation through which the concentration was brought about. The evidence, as presented, does not convince me that the deposition from oceanic waters may not have been in some younger formation than the Galena limestone, in a formation which is completely removed. It is somewhat difficult to understand how a formation, only partly removed, can have contributed through a downward circulation the rich ore bodies which lie near the top of the formation.

E. R. BUCKLEY.

ROLLA, MISSOURI,
July 6, 1907.

# RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. F. LOUGHLIN AND A. H. HUGHEY.

## METALLIFEROUS DEPOSITS.

### COPPER.

**Copper Mining an Important Industry in British Columbia.** By E. JACOBS. B. C. Min. Rec., March, 1907. Pp. 13.

**Die Entstehung der Kupfererzlagerstätte von Corocora und verwandter Vorkommnisse in Bolivia.** By G. Steinmann. Rosenbusch-Festschrift. 1906. Pp. 335–368. With two plates and four text figures. (Abstract in Geol. Centralb., IX., 7, 1907, p. 296.)

**Notice géologique et minière sur le bassin cuprifère du Kouilon-Niari (Congo Français).** By D. LEVAT. Ann. des Mines. T. XI., 1907. Pp. 5–65. With plates I–IV.

**Región cuprifera de Cachicachi, provincias de Tarma y Jauja, Peru.** By F. G. FUCHS. Bol. de minas, ind. y contr., 1907. Part I., Series II. Pp. 41–46.

**The Copper Mines of the World.** By WALTER HARVEY WEED. New York. 1907. Pp. 375. With illustrations.

### GOLD.

**Black Sands of New Zealand, the Pacific, and Tierra del Fuego.** By C. C. LONGRIDGE. The Mining Jour. Vol. LXXXI, April 20, 1907. P. 522.

**The Ballarat East Gold Field.** By J. W. GREGORY. Memoirs Geol. Survey Victoria, No. 4. 1907. Pp. 52. With plates. Melbourne.

**The Berringa Gold Field.** By WM. BARAGWANATH. Memoirs Geol. Survey Victoria, No. 5. 1907. Pp. 17. With plates. Melbourne.

**Juneau Gold Belt, Alaska.** By A. C. SPENCER, and a reconnaissance of Admiralty Island, by C. W. WRIGHT. Bull. U. S. Geol. Survey No. 287. 1906. Pp. 161.

**A Brief Sketch of the Lena District, Siberia.** By C. W. PURINGTON. The Mining Journal. LXXXI., April 20, 1907. P. 517. With sketch map.

**The Deep Leads and the Old Divide in the Ballarat District.** By W. H. CALLISTER. Ballarat School of Mines Students' Magazine. Vol. IX., No. 4, 1906. Pp. 3.

**Distribution of Bedded Leads in Relation to Mining Policy.** By J. E. WOODMAN. Jour. Min. Soc. Nova Scotia. Vol. X. Pp. 18.

**Geological Map, Showing the Relationship of the East, Central, and West Witwatersrand to the Potchefstrom, Klerksdorp, and Venterskroom Goldfields, South Transvaal.** Compiled by T. KASSNER, from personal observation. £30. London, George Philip and Sons, Limited.

**Le gîte auroplatinifère de Ruwe (Katanga).** By H. BUTTENBACH. Congr. intern. des mines, etc. Liège, 1905. Sect. de Géol. appl. Pp. 437–450. With 5 figures.

**Gold Mining in the Ural and Tomsk Districts.** By A. L. SIMON. The Mining Journal. Vol. LXXXI. P. 698. May 25, 1907.

**Das Goldvorkommen im Siebenbürgischen Erzgebirge und sein Verhältnis, zum Nebengestein der Gänge.** By M. v. PÁLFY. Zeit. f. prakt. Geol. Jg. XV., Heft 5. 1907. Pp. 144–148. With figures 42–44.

**The Laverton, Burtville, and Erlestoun Auriferous Belt, Mt. Margaret Goldfield.** By C. G. GIBSON. Western Australian Geol. Surv., Bull. No. 24. 1906. Pp. 77. With many geologic maps.

**Mining in the District of Taviche, Oaxaca, Mexico.** By R. H. WILLIAMS. The Mining Journal. Vol. LXXXI. P. 553, April 27, 1906.

**Some Croydon Gold Mines.** By B. DUNSTAN. Queensland Gov't. Min. Jour., May, 1907. Pp. 12.

**Gold Nuggets from New Guinea Showing a Concentric Structure.** By A. LIVERSIDGE. Jour. and Proc. of the Roy. Soc. of N. S. Wales. Vol. 40, 1906. Pp. 161–162.

**The Undeveloped Gold Deposits of New Zealand.** By W. GREEN. New Zeal. Mines Rec., April 16, 1907. Pp. 10½.

**Monthly Analysis of Gold Production in the Transvaal, May, 1907.** The Transvaal Chamber of Mines, Johannesburg.

**Étude Pratique des Minerals Aurifères Principalement dans les Colonies et Pays Isolés.** Par N. Dégoutin, Extrait du Bulletin de la Société de l'Industrie minerale. Tome V. 1906. Pp. 281. Paris.

## IRON.

**Der Eisenerzbergbau und der Eisenhüttenbetrieb an der Lahn. Dill und in den benachbarten Revieren. Eine Darstellung ihrer wirtschaftlichen Entwicklung und gegenwärtigen Lage.** By G. EINECKE. Jena, G. Fischer, 1907. Heft 2 der "Mitt d. Ges. f. wirtschaftl. Ausbildung," Frankfurt a. M. Pp. 67. With one map i. M. 1:24000.

**Die Eisenerzlagerstätten von Sydvaranger und die Sonderung oden Differentiation von Eruptivmassen durch Druck.** By G. HENRIKSEN. Osterr. z. f. B. u. H. 54, 1906. No. 13. P. 168.

**Die Eisenerzvorräte Deutschlands.** By H. WEDDING. Verh. d. ver. z. Beförd. d. Gewerbefleisses. 1907. Pp. 198–210.

## LEAD AND ZINC.

**The Downtown District of Leadville, Colo.** By S. F. EMMONS and J. D. IRVING. Bull. U. S. Geol. Survey No. 320. 1907. Pp. 75. With maps.

**Zinc and Lead Deposits of the Upper Mississippi Valley.** By H. F. BAIN. Bull. U. S. Geol. Survey No. 294. 1906. Pp. 155. With plates.

**Die Bleiglanzlagerstätten von Mazarrón in Spanien.** By R. PILZ. Von der Kgl. Technischen Hochschule zu Dresden in verbindung mit der Kgl. Bergakademie zu Freiberg zur Erlangung der Würde eines Doktor-Ingenieurs genehmigte Dissertation. Freiberg i. S., Cray & Gerlach. 1907. Pp. 52. With 17 figures. (Abstract in Geol. Centralb., IX., 9, 1907, P. 430.)

**Vorkommen, Gewinnung und Aufbereitung der Blei-und Kupfererze des Pinar de Bédar in Süd-Spanien.** By O. PÜTZ. Z. f. d. B. H. u. S. im Pr. Staate. 54, 1906. Pp. 675–683. With 11 text figures. (Short abstract in Geol. Centralb., IX., 7, 1907, p. 297.)

## SILVER.

**The Cobalt Mining District.** By Dr. R. BELL, F.R.S. Can. Min. Jour. Vol. I., No. 8, 1907. Pp. 246–248.

## TIN.

**Mount Cudgewa Tin Field.** By Prof. J. W. GREGORY. Bull. Geol. Survey Victoria. No. 22. 1907. Pp. 4. Melbourne.

**Tin-Ore Deposits of Bolivia.** By G. STEINMANN. The Mining Journal. Vol. LXXXI., p. 453. April 6, 1907. (Translated from Proceedings of the Deutsche geologischen Gesellschaft.)

**Das Vorkommen von Zinnstein im Fichtelgebirge und dessen Gewinnung im Mittelalter.** By A. SCHMIDT. Z. f. d. B. H. u. S. im Pr. Staate. 54, 1906. Pp. 377–382. With 1 map and one sketch in the text. (Short abstract in Geol. Centralb., IX., 7, 1907, p. 297.)

## NON-METALLIC DEPOSITS.

### ASPHALT.

**Der Asphalt.** By K. WOLFF. Deutche Warenkunde, I. 1906. P. 91.

**Uber den griechen Asphalt und seine technische Bedeutung.** By A. Ch. VOURNASOS. Dinglers Polyt. J. Bd. 321, H. 13. 1906. Pp. 200–204. With one text figure, and one graphic scheme. (Abstract in Geol. Centralb., IX., 7, 1907, p. 302.)

### CLAY.

**Clays of Wisconsin and their Uses.** By HEINRICH RIES. With a report on Molding Sands, by H. RIES and F. L. GALLUP. Wisconsin Geol. and Nat. Hist. Survey, Bull. No. 15. 1906. Pp. 259. Madison.

**Clay and the Clay Industry of Ontario.** By M. B. BAKER. Ontario Bureau of Mines. Vol. XV., Part II. 1906. Pp. 127. Illustrated.

### COAL.

**Die Braunkohlenvorkommen Bayerns.** By K. OEBBEHE and M. KERNAUL. Braunkohle. V. 1907. Pp. 799–806. With figures 317 and 318.

**Classification of Coal.** By A. L. MACCOLLUM. Can. Min Jour. May 1, 1907. P. 1.

**Formation et recherche des combustibles fossiles.** By M. LIMIÈRE. Congr. intern. des mines, etc. Liège, 1905. Sect. de Géol appl. Pp. 203–231. With 10 figures.

**Note sur les recherches effectuées en Meurthe-et-Moselle pour retrouver les prolongement du bassin houiller de Sarrebrück en territoirê français.** By F. VILLAIN. Congr. intern. des mines, etc. Liége, 1905. Sect. de Geol. appl. Pp. 325–334.

**Das Steinkohlengebiet nordöstlich der Roer nach den Ergebnissen der Tiefbohrungen und verglichen mit dem Cardiff-Distrikt.** By P. KRUSCH and WUNSTORF. Essener Glückauf. Pp. 425–437. With plates 8 and 9.

**Geology of the South Wales Coal Field,** Part IX, west Gower and the country around Pembrey, sheet 246 of map. By AUBREY STRAHAN. Memoirs of the Geological Survey, England and Wales. 1907. Pp. 50. London.

**Notes on the Mineral Fuel Supply of Canada.** By R. W. ELLS. Proceedings and transactions of the Roy. Soc. of Canada. 2d ser., vol. 12. 1906. Section IV. Pp. 267–291.

## DIAMOND.

**Paardeberg Mines and District II.** By H. D. GRIFFITHS. So. African Min. Rev. March 30, 1907. P. 1.

**On the Vaal Diamond Diggings.** So. African Min. Rev. March, 1907. Pp. 14.

## GRAPHITE.

**Graphite: Its Occurrence and Uses.** Bull. Imp. Inst. Vol. V., No. 1. 1907. Pp. 14½. (Continued.)

## PETROLEUM.

**Notice sure la constitution du bassin houiller de Liège.** By O. LEDOUBLE. Congr. interm. des mines, etc. Liège, 1905. Sect. de Géol. appl. Pp. 553–594. With one figure and eight plates.

**Le nouveau bassin houiller de la Lorraine française.** By F. LAUR. Congr. intern. des mines, etc. Liège, 1905. Sect. de Géol. appl. Pp. 391–436. With one plate.

**Le Origini del petrolio.** By D. PANTANELLI. Boll. Soc. Géol. ital. XXV., 3°. Pp. 795–802. Rome, 1906.

**Das Erdöl und seine Verwandten. Geschichte, physikalische und chemische Beschaffenheit, Vorkommen, Ursprung, Auffindung und Gewinnung des Eudöles.** By H. HÖFER. Second Edition. Braunschweig, F. Wieweg & Sohn, 1906. 8°. Pp. XVII + 279. With 18 abb., 10 Mk.

**Le Pétrole au Canada.** Jour. du Pétrole. April 10, 1907. Pp. 1½.

**Die Petroleumfelder auf Sackalin.** By TULTSCHINSKY. St. Petersburg official "Handels- u. Industrie Zeit." March 3, 1907. Petroleum. II. 1907. Pp. 496–498.

**La question du pétrole en Roumanie.** By D. STURDYA. Berlin, Puttkammer & Mühlbrecht, 1906. Pp. 92.

## PHOSPHATE.

**Die Phosphatlagerstätten Frankreichs.** By O. TIETZE. Zeit f. Prakt. Geol. Jg. XV., Heft 4. 1907. Pp. 117–124.

## SALT.

**Die neuere Entwicklung der Kaliindustrie und des Kalisyndikates.** By R. HEIMANN. Schmollers Jahrb. 1906. Heft 4.

**Das Recht zur Aufsuchung und Gewinnung von Kalisalzen in den ausserpreussischen Bundesstaaten.** By THIELMANN. "Kali." I. 1907. Pp. 137–145.

## SULPHUR AND PYRITE.

**Note sur les conditions économiques de l'exploitation du soufre en Sicile et en Louisiane.** By L. AGUILLON. Ann. des Mines. T. X. 1906. Pp. 599–617.

**The Origin of Deposits of Pyrites.** By A. B. WILLMOT. Paper read before Can. Min. Inst., March, 1907. Pp. 11.

## WATER.

**Ueber die Bewegung von Grundwasser.** By F. WÜNNEMANN. Jour. f. Gasbeleuchtung und Wasserversorgung. V. 26. Jan., 1907.

**Ueber die Grundwasserverhältnisse der Stadt Breslau.** By F. BEYSCHLAG and R. MICHAEL. Zeit. f. prakt. Geol. Jahrg. XV., Heft 5. 1907. Pp. 153–164. With figure 47.

## UNCLASSIFIED AND GENERAL.

**Mining and Geological Notes on the Walhalla and Wood's Point Districts.** By E. J. DUNN. Bull. Geol. Survey Victoria. No 21. 1907. Pp. 10. Melbourne.

**Boletín de la Secretaría de Fomento, II.** Minas y Metalurgia. Año VI., Num. 9. 1907. Pp. 762–846. Mèxico.

**Geologic Reconnaissance in Southwest Nevada and Eastern California.** By S. H. BALL. Bull. U. S. Geol. Survey No. 308. 1907. Pp. 218.

**Mineral Resources of Alaska.** By A. H. BROOKS and others. Bull. U. S. Geol. Survey No. 314. 1907. Pp. 235.

**Report of Mine Inspector for Indian Territory for 1906.** Department of the Interior Annual Reports. 1907. Pp. 659–712.

**Australian Mining and Metallurgy.** By DONALD CLARK. 1904. Pp. 534. Melbourne.

**A Textbook of Mining Geology.** By JAMES PARK. 1906. Pp. 219. London, Charles Griffin and Co.

**Jahresbericht der Kgl. Ungarischen geologischen anstalt für 1905.** 1907. Pp. 292. Budapest.

**Statistische Zusammenstellungen über Blei, Kupfer, Zink, Zinn, Aluminum, Nickel, Quecksilber, und Silber, 1897–1906.** 1907. Pp. 111. Frankfurt-am-Main.

**Report on the Mineral Resources of Ballarat.** By R. A. F. MURRAY, and Reports on the coal Fields on Loutit Bay, Apollo Bay, and the Wannon: Report of progress Geol. Survey Victoria, No. 1. 1874. Pp. 130. Melbourne.

**Ann. Rept. of the Under Secretary for Mines, Queensland, for 1906.** 1907. Pp. 170. Brisbane.

**Minerals from Lyon Mountain, Clinton County, N. Y.** By H. P. WHITLOCK. N. Y. State Museum, Bull. 107. Geology 12. 1907. Pp. 55–74.

**General Report of the Geological Survey of India for the Year 1906.** T. H. HOLLAND, Director. Records of Geol. Surv. of India. Vol. XXXV., part 1. 1907. Pp. 59.

**Geologische Verhältnisse des zwischen Wagyveszverés und Krasznahorkaváralja gelegenen Abschnitts des Szepes Gömörer Erzgebirges.** By E. REGULY. Jahresber. d. Kgl. Ungar. Geol. Anstalt für 1905. Budapest, 1907. Pp. 171–183.

**The Geology and Ore Deposits of Franklin Camp, B. C.** By R. W. BROCK. Can. Min. Jour. Vol. I., No. 8. 1907. Pp. 233–236.

**Ueber die mechanischen Vorgänge im Innern und an der Oberfläche der Erde mit Berücksichtigung der sogenannten "faulen Ruscheln" am Harz.** By O. HOPPE. Zeit. f. prakt. Geol. Jg. XV., Heft 5. 1907. Pp. 139–143.

**Minerales que se benefician en Llaray, Santiago de Chuco, Peru.** By A. CALONGE. Bol. de minos, ind. y constr. 1907. Part I., Series II. Pp. 46–51. With two figures.

**Note sur la Géologie et les Mines de la Région Comprise Entre Lao-Kay et Yunnan-Sen.** By H. LANTENOIS. Ann. des Mines. Tome XI., Livre 3. 1907. Pp. 82½.

**Notes on the Mineral Fuel Supply of Canada.** By R. W. ELLS, LL.D. Can. Min. Jour. Vol. I., Nos. 7 and 8. (To be continued.)

**The Similkameen District of British Columbia.** By C. CAMSELL. B. C. Min. Rec. April, 1907. Pp. 6½. (Abstract from Summary Report of Geol. Surv. of Canada for 1906.)

**Zur Frage der Entwässerung lockerer Gebirgsschichten als Ursache von Bodensenkungen, besonders im rheinischwest-fälischen Steinkohlenbezirk.** By R. BÄRTLING. Zeit. f. prakt. Geol. Jg. XV., Heft 5. 1907. Pp. 148–153. With figures 45 and 46.

**Sur la géologie du cercle de Maevetanana, Madagascar.** By J. COLCANAP. Bull. Soc. Géol. de France. T. VI. 1906. Pp. 164–170. With three figures and one geologic map, scale 1 : 1,000,000.

**Les Stratamètres. Appareils pour mesurer l'inclinasion des terrains.** By F. HOFER. Gémê Civ. April 20, 1907. Pp. 2.

**Benitoite, a new California Gem Mineral.** By G. D. LOUDERBACK with chemical analysis by W. C. BLASDALE. Univ. of Cal. Publications, Bull. Dept. of Geol. Vol. 5. 1907. Pp. 149–153.

**Boletin de la Sociedad nacional de mineria, Revista Minera.** Year IX, Nos. 103 and 104. Pp. 255–300. 1906. Lima, Peru.

**On the Origin of Gases Evolved by Mineral Springs.** By R. J. STRUTT. Proceedings of the Royal Society. Vol. 79. 1907. Pp. 436–439.

**Eighth Annual Report of the Mining Industry of Idaho** (for 1906). 1907. Pp. 175.

**Report of the Department of Mines,** 1906. 1907. Pp. 67. Cairo, Egypt.

**Catalog of Minerals, Rocks and Ores in the U. S. National Museum.** Bulletin No. 53, part II. U. S. Nat. Mus. 1907. Pp. 370.

**Les Richesses minérales de L'Algérie et de La Tunise.** By PAUL F. CHALON. 1907. Pp. 99. Paris.

**Die Fahlerz- und Quecksilbererzlagerstätten Bosniens und der Hercegovnia.** By FRIEDRICH HATZER. Berg- und Hüttenmännisches Jahrbuch. Vol. 55. 1907. Pp. 146–265. Vienna.

**Minas y Metalurgia.** Boletin de la Secretaria de Fomento, II. Year VI., No. 10. 1907. Pp. 847–951. Mexico.

**Mines and Quarries: General Report and Statistics for 1905. Part IV., Colonial and Foreign Statistics.** 1907. Pp. 289–497. London.

**Notizie sui Giacimenti di lignite dell'Iglesiente.** By B. GALDI. Publicazione del Corpo reale delle miniere. 1907. Pp. 55. 6 plates. Rome.

**Transactions of the Manchester Geological and Mining Society, Session 1906–1907.** Parts III. and IV. Vol. XXX. 1907. Pp. 47–80. Manchester.

**Oil and Gas Fields of Greene County, Pa.** By R. W. STONE and F. G. CLAPP. Bull. U. S. Geol. Survey No. 304. 1907. Pp. 110. 3 plates.

**Preliminary Report on the Santa Maria Oil District, Santa Barbara County, Cal.** By RALPH ARNOLD and ROBERT ANDERSON. Bull. U. S. Geol. Survey No. 317. 1907. Pp. 69. 2 plates.

**Osservazioni sulla memoria di L. De Launay "La metallogenie de l'Italie, etc.," Mexico, 1906.** By B. LOTTI. 1907. Pp. 20. Rome.

**Sulla provenienza dell'acido borico nei soffioni della Toscana.** By B. LOTTI. Reprint from Rassegna Mineraria e della Industria Chimica. Vol. XXVI, 1907. Pp. 5. 1907. Turin.

**Third Annual Report of the Mines Department of Orange River Colony for 1905–6.** 1907. Pp. 47. Bloemfontein.

**Gypsum Deposits of New Brunswick.** By L. W. BAILEY. Proceedings and transactions of the Roy. Soc. of Canada, 2d series. Vol. 12. 1906. Section IV. Pp. 5–15.

**Annual Report of the Minister of Mines for Year Ending December 31, 1906,** being an account of mining operations for gold, coal, etc., in the province of British Columbia. 1907. Pp. 276. Victoria, B. C.

**Bulletin de la Société de l'Industrie Minérale,** 4th series. Vol. VI. 1907. Pp. 553–847. Saint-Etienne.

**The Mining and Quarry Industry of New York State, Report of Operations and Productions During 1906.** By D. H. NEWLAND. Pp. 80. 1907. Albany.

**Records of the Geological Survey of India.** Vol. XXXV, part 2. Pp. 79–121. 1907. Calcutta.

**Yacimiento de Borax de la Laguna de Salinas.** By ALBERTO JOCHAMOWITZ. Boletin del Cuerpo de Ingenieros de Minas del Peru, No. 49. Pp. 30. With 1 plate and 2 maps. 1907. Lima.

**Note on the Occurrence of Precious Opal at Tooraweanah, Warrumbungle Mountains.** By E. T. PITTMAN. Records of the Geological Survey of N. S. W. Vol. 8. 1907. Pp. 187–188. 1 plate.

**Boletin de la Secretaría de Fomento, II., Minas y Metalurgia.** Year VI., No. 11. Pp. 953–1126. 1907. Mexico.

**Comparative Statistics of Lead, Copper, Spelter, Tin, Aluminum, Nickel, Quicksilver and Silver.** Compiled by the metallgesellschaft, etc., 13th annual issue. Pp. 111. 1907. Frankfort on the Main.

**Story of the First Pennsylvania Copper Mine.** By GEORGE GEIST. Reprint from Mineral Collector, 14. August 1907.

**Annual Progress Report of the Geological Survey of Western Australia for the Year 1906.** Pp. 31. 1907. Perth.

**Report of the Secretary for Mines of Southern Rhodesia for Year Ending March 31, 1907.** Pp. 24. 1907. Salisbury.

**Records of the Geological Survey of New South Wales.** Vol. VIII. Part III. 1907.

**Progress of the Mineral Industry of Tasmania for the Quarter Ending March 31, 1907.** By W. H. TWELVETREES. Government Geologist. Pp. 19. 1907. Tasmania.

**Boletin del Cuerpo de Ingenieros de Minas del Peru.** Nos. 47, 48, 49. 1907. Lima.

**Annual Report of the Mineral Industries of Canada for 1905.** Section of Mines, Geological Survey of Canada. Pp. 174. 1907. Ottawa.

**Mining, Mineral and Geological Law.** By CHARLES H. SHAMEL. 1907. New York.

# SCIENTIFIC NOTES AND NEWS[1]

THE FLORIDA LEGISLATURE has provided for the establishment of a State Geological Survey. Dr. E. H. Sellards, formerly of the State University, has been appointed by Governor Broward to the office of State Geologist. The offices of the Survey are at the State capital, Tallahassee, Fla.

PROFESSOR GEO. D. LOUDERBACK, of the University of California, has lately described a new gem mineral from the Mount Diablo Range, California, which he has named benitoite. The new mineral is a very acid titano-silicate of barium with the probable formula $BaTiSi_3O_9$. It has a beautiful blue color, rivalling the sapphire in this respect while surpassing that gem in brilliancy. It is associated with another mineral, not yet fully investigated, which appears to be also new to science.

A NEW LIST of the publications of the United State Geological Survey (except topographic maps) has just been issued and is obtainable on application to the Director. It is perhaps not as widely known as it should be, that many publications of the survey, as well as of other government bureaus, which are out of stock at the bureaus themselves may still be obtained, at the original cost of printing, from the Superintendent of Documents, Washington, D. C., who furnishes price lists on application.

ALTHOUGH diamonds have been found in at least thirty localities in the United States, the only one where they occur in place has recently been discovered and has been investigated by Mr. George F. Kunz and Dr. H. S. Washington. They occur in an altered peridotite, similar to that of the South African

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

mines, which forms a small stock near Murfreesboro, Pike County, Ark. The first two stones were found August 1, 1906, and many have been picked up since, the total number found at last report being 130. Many are white and of good water, others are yellow and some are brown bort. The two largest stones weigh six and one half carats, one being an exceedingly fine white and the other brown. They are found on the surface as well as within the greenish, friable, decomposed peridotite. The property is being actively prospected.

DR. JAMES E. TALMAGE has resigned his position as professor of geology at the University of Utah in order to devote himself to mining geology. Professor Talmage has occupied the chair since its establishment as an endowed professorship thirteen years ago. In 1897 he retired from the presidency of the University of Utah to continue his work in geology. His successor in the department of geology is Dr. Fred J. Pack, who is one of his former students and a graduate from Columbia University, now professor at the Brigham Young College.

PROFESSOR JOHN D. IRVING is not expected to return from Alaska until October.

ARRANGEMENTS FOR COÖPERATION in the investigation of underground waters and of the stratigraphy of Florida have been completed between the U. S. Geological Survey and the newly organized Geological Survey of Florida. Mr. M. L. Fuller, of the national survey, will have charge of the stratigraphic investigations, which will form a part of the broader investigations of the Atlantic and Gulf Coastal Plains being conducted by the United States and the local State Surveys under the direction of Mr. Fuller. The underground water studies will be divided between the state and the national surveys.

DR. L. W. STEPHENSON has been appointed assistant geologist on the U. S. Geological Survey, and will be engaged for the next two years in the investigation of the geology and water resources of Virginia and the Carolinas.

THE FOLLOWING PAPERS of interest to economic geologists were read at the thirty-sixth general meeting of the American

Chemical Society, held in Toronto, Canada, on June 27–29: "Some Experiments to Determine the Amount of Volatile Matter in Coal," A. Bement; "Canadian Shales and Products," Charles Baskerville and W. A. Hamor; "Pure Coal and the Deterioration of Coal Samples," S. W. Parr and W. F. Wheeler, reported by title; "Vanadium Sulphide, Patronite, and its Mineral Associates from Minasragra, Peru," W. F. Hillebrand and W. T. Schaller; "The Mercury Minerals of Terlingua, Texas, W. F. Hillebrand and W. T. Schaller, reported by title.

THE GEOLOGICAL SURVEY OF SOUTH DAKOTA will confine its field-work for 1907 to that part of the State known as the Bad Lands. Special attention will be given to (1) the collection of fossils, (2) the collection of plants, including grasses, and (3) a general study of the geological formations. A party of five left the university for field-work on July 10th.

DR. GEORGE OTIS SMITH, Director of the U. S. Geological Survey, left Washington on August 30 for an official journey through the western states.

DR. WHITMAN CROSS of the U. S. Geological Survey, Professor J. P. Iddings of the University of Chicago, and Professor F. D. Adams of McGill University, Canada, have been spending part of the summer together in the Alps.

MR. ALFRED MAYER ROCK, a young mining engineer in the geological department of the American Smelters Securities Co., was killed on August 7, 1907, in the Santa Francisca mine at Asientos, Mexico, by asphyxiation, while aiding as a volunteer, in controlling an accidental fire in the mine. Mr. Rock was a graduate of Harvard University and prior to his engagement by the Guggenheim companies was a geological assistant with the U. S. Geological Survey at Bisbee, Ariz., Cripple Creek, Colo., and at Park City, Utah.

A KNOWLEDGE OF THE CONDITIONS that govern the accumulation of petroleum in pools is of the greatest practical value to the oil men, and investigations to determine these conditions have been carried on for a number of years by the geologists of the U. S. Geological Survey in various oil-producing districts.

The results of some recent work of this kind in Pennsylvania, Ohio and West Virginia, by Messrs. W. T. Griswold and M. J. Munn, have just been published by the Survey as Bulletin No. 318.

DR. C. H. GORDON, who for the last two years has been conducting an investigation of Texas ground waters for the U. S. Geological Survey, will go to Knoxville, Tenn., about September 1, to occupy the newly established chair of geology and mineralogy of the State University.

AN ADVANCE CHAPTER from "Mineral Resources of the United States, Calendar Year 1906," on the production of coal in 1906, by E. W. Parker, Chief Statistician of the U. S. Geological Survey, will be ready for distribution by the Survey in September.

ACCCORDING TO THE *Canadian Mining Journal,* Mr. D. B. Dowling, late of the Geological Survey of Canada, and at present in charge of a prospecting party sent out by German capitalists, has discovered coal not far from the Yellow Head Pass, where the Grand Trunk Pacific and Canadian Northern will probably cross the mountains.

MR. MYRON L. FULLER has resigned from the U. S. Geological Survey to devote himself to cranberry culture in New England.

MR. F. C. LINCOLN has accepted the professorship of geology and mineralogy at the Montana State School of Mines. He will continue his practice as consulting geologist and mining engineer in so far as his new duties permit.

THE UNITED STATES GEOLOGICAL SURVEY announces new publications as follows:

Professional Papers:

53. Geology and water resources of Bighorn basin, Wyoming, by C. A. Fisher. 72 pp., 16 pls.

Bulletins:

304. Oil and gas fields of Greene County, Pa., by R. W. Stone and F. G. Clapp. 110 pp., 3 pls.

317. Preliminary report on Santa Maria oil district, Santa Barbara County, Cal., by Ralph Arnold and Robert Anderson. 69 pp., 2 pls.

318. Geology of oil and gas fields in Steubenville, Burgettstown, and Claysville quadrangles, Ohio, West Virginia, and Pennsylvania, by W. T. Griswold, and M. J. Munn. 196 pp., 13 pls.

320. Downtown district of Leadville, Colo., by S. F. Emmons and J. D. Irving. 75 pp., 7 pls.

324. San Francisco earthquake and fire of April 18, 1906, and their effects on structures and structural materials, by G. K. Gilbert, R. L. Humphrey, J. S. Sewell, and Frank Soulé. 170 pp., 57 pls.

Water-Supply Papers:

195. Underground waters of Missouri, their geology and utilization, by E. M. Shepard. 224 pp., 6 pls.

199. Underground water in Sanpete and Central Sevier valleys, by G. B. Richardson. 63 pp., 6 pls.

Topographic Map:

Yosemite Valley, Mariposa County, Cal. Size, 19 by 38 inches; scale, 2½ inches to the mile. Elevations shown by contour lines. *Price, 10 cents.*

The Geological Survey has a limited number of copies of these publications for free distribution (except the map, whose price is stated), and some have been delivered to Members of Congress for distribution. The Survey cannot give more than one copy to any person, and general requests for all the papers cannot be complied with unless a satisfactory reason why every one is desired is given. Payment for sale publications should be made by postal or express money order, payable to the Director, U. S. Geological Survey, or in cash—the *exact amount*. Checks, drafts, and postage stamps cannot be accepted. Applications sent to the Geological Survey should be addressed to The Director.

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